Fish and Water Management Tools Project Assessments: Record of Management Strategy and Decisions for the 2007-2008 Water Year

K.D. Hyatt and M.M. Stockwell

Fisheries and Oceans Canada
Science Branch, Pacific Region
Pacific Biological Station
Nanaimo, BC
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FISH AND WATER MANAGEMENT TOOLS PROJECT ASSESSMENTS: RECORD OF MANAGEMENT STRATEGY AND DECISIONS FOR THE 2007-2008 WATER YEAR

by

K.D. Hyatt and M.M. Stockwell

Fisheries and Oceans Canada
Science Branch, Pacific Region
Pacific Biological Station
Nanaimo, BC V9T 6N7

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The operational deployment and testing of the Fish-and-Water Management Tools decision support system (hereafter identified as FWMT) in the Okanagan during 2007-2008 was made possible by the dedication and hard work of many individuals from several organizations:

- Rick Klinge from Douglas County Public Utility District (DCPUD) in Washington State provided not only monetary support but also the necessary confidence to implement multi-year trials to determine fish production benefits that may be achieved through deployment of a new generation of fish-and-water management tools.
- Deployment and testing of FWMT is executed under the authority of the three-party (Fisheries & Oceans Canada-DFO, BC-Ministry of Environment-MOE, Okanagan Nation Alliance-ONA) Canadian Okanagan Basin Technical Working Group (COBTWG) chaired by Steve Matthews (MOE).
- Des Anderson of the WSD Office in Penticton was "manager of record" during the 2007-08 fish-and-water year.
- Paul Askey from BC-MOE Fisheries provided advice regarding status and trends for brood-year 2007 kokanee spawning and egg or alevin incubation at Okanagan Lake beaches.
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- Paul Rankin and Rick Ferguson from DFO helped design and execute acoustics, trawl and survey work associated with assessing annual to seasonal production variations of juvenile sockeye salmon in the Okanagan River and Osoyoos Lake.
- Clint Alexander of ESSA Technologies Ltd. always made himself available to repair code "bugs", investigate problems, and carefully explain the intricacies of FWMT software and the model to new and experienced users.
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- Finally, congratulations are due to all members of the 2007-2008 FWMT Operations Team who demonstrated that exceptional levels of interagency and inter-party collaboration have the potential to produce exceptional levels of success for integrated resource management.

ABSTRACT

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The fish-and-water management tools (FWMT) system is a coupled set of 4 biophysical models of key relationships (among climate, water, fish and property) used to predict consequences of water management decisions (represented in a fifth decision-rules model) for both natural systems (e.g. fish production and biodiversity maintenance) and human systems (e.g. flood control around the lake and river, irrigation, recreation). A new fish and water year began October 1, 2007, just prior to the initiation of sockeye and kokanee salmon spawning. At the beginning of each month from January 2008 to June 2008, estimates of water inflows to Okanagan Lake were provided by the BC Ministry of Environment River Forecast Centre and entered into FWMT. Model users accessed web sites and reports including trends in current snow-packs as well as recent and forecast climatic conditions to predict the magnitude and timing of future water runoff. FWMT facilitated integration of these data with real-time information on fish life-history stage plus river and lake conditions to predict the impacts of a range of water storage and release scenarios for fish and other water users. FWMT scenarios were reviewed by an Operations Team to support an ongoing dialogue during the 2007-08 fish-and-water year regarding prudent water management decisions.

Development of FWMT Scenarios and maintenance of an ongoing dialogue among its users resulted in a water management regime that satisfied the requirements of fish and other water users such that: (1) little risk materialized for loss of kokanee eggs or alevins prior to spring fry emergence at Okanagan Lake beaches, (2) sockeye eggs and alevins, incubating in the Okanagan River near Oliver, were not subjected to any acute dewatering or scour events, (3) water managers were able to achieve all key benchmarks in Okanagan Lake and River, satisfying lake level and discharge requirements for fisheries resources, recreation preferences, and domestic and agricultural water supplies (4) potential reductions to survival and growth of sockeye fry rearing in Osoyoos Lake in 2008 were avoided due to the identification of an early need for water conservation measures. The subsequent ability of managers to initiate a supplemental release of stored water in mid-September reduced the severity of potential impacts on sockeye fry of an acute temperature-oxygen "squeeze" that developed in the hypolimnion of Osoyoos Lake in late summer.

Following four years of real-time deployment, FWMT achieved acclaim as a highly innovative and successful decision support system that allows resource managers to balance off the complex suite of water demands in the Okanagan basin. In recognition of this achievement, the project and its team members were presented with a British Columbia Premier's Service Award for innovation and excellence in the Public Service in February of 2008.

RÉSUMÉ

Hyatt, K.D. et Stockwell, M.M. 2013. Fish and Water Management Tool project assessments: Record of management strategy and decisions for the 2007-2008 water year. Rapp. manus. can. sci. halieut. aquat. 3022: 3022: ix + 70 p.

Le système d'outils de gestion des poissons et des eaux (Fish-and-Water Management Tools – FWMT) est un ensemble couplé de quatre modèles biophysiques de relations clés (le climat, les eaux, les poissons et la propriété) utilisé pour prédire les conséquences des décisions en matière de gestion des eaux (représentées dans un cinquième modèle de règle de décision) pour les systèmes naturels (p. ex., production des poissons et maintien de la biodiversité) et les systèmes humains (p. ex., prévention des inondations près des lacs et des rivières, irrigation, activités récréatives). Un nouveau cycle annuel a débuté le 1er octobre 2007 pour les eaux et les poissons, juste avant le début du frai des saumons rouge et kokani. Au début de chaque mois, de janvier 2008 à juin 2008, des relevés sur la circulation des eaux vers le lac Okanagan ont été fournies par le Centre de prévision des régimes fluviaux du ministère de l'Environnement de la Colombie-Britannique; ces prévisions ont été entrées dans le FWMT. Les utilisateurs du modèle ont accédé à des sites Web et à des rapports portant notamment sur les tendances actuelles des accumulations de neige ainsi que les conditions climatiques récentes et prévues, afin de prédire le volume et le moment de l'écoulement futur. Le FWMT a facilité le regroupement de ces données avec les données en temps réel sur les stades de vie des poissons et les conditions des rivières et des lacs afin de prédire les effets d'une vaste gamme de scénarios de stockage et d'apport d'eau sur les poissons et d'autres utilisateurs de la ressource. Les scénarios du FWMT ont été examinés par une équipe opérationnelle afin d'appuyer le dialogue soutenu pendant le cycle annuel 2007-2008 des eaux et des poissons en ce qui concerne la prise de décisions prudentes relativement à la gestion des eaux.

L'élaboration de scénarios à l'aide du FWMT et la poursuite du dialogue entre ses utilisateurs ont rendu possible un régime de gestion des eaux qui satisfait aux exigences des poissons et des autres utilisateurs de l'eau de sorte que : 1) peu de risques se sont matérialisés quant à la perte d'œufs ou d'alevins vésiculés de saumon kokani avant l'émergence des alevins sur les plages du lac Okanagan au printemps; 2) les œufs et les alevins vésiculés de saumon rouge en incubation dans la rivière Okanagan près d'Oliver n'ont pas été sujets à des événements aigus d'assèchement ou d'affouillement; 3) les gestionnaires des ressources aquatiques ont réussi à atteindre tous les importants niveaux de référence dans le lac et la rivière Okanagan, satisfaisant aux exigences en matière de niveau d'eau et de décharge pour les ressources halieutiques, les préférences récréatives et les alimentations en eau résidentielles et agricoles; 4) et les possibles réductions du taux de survie et de croissance des alevins de saumon rouge dans le lac Osoyoos en 2008 ont été évitées grâce à la détermination précoce de la nécessité de mesures de conservation de l'eau. Comme les gestionnaires ont été en mesure de faire un apport supplémentaire d'eaux stockées à la mi-septembre, il a été possible de réduire la gravité des impacts potentiels, sur les alevins de saumon rouge, de la compression température-oxygène aiguë qui s'est développée dans l'hypolimnion du lac Osoyoos à la fin de l'été.

Après quatre années d'utilisation en temps réel, le FWMT a été célébré en tant que système d'appui décisionnel hautement innovateur et performant qui permet aux gestionnaires de la ressource d'équilibrer toute la gamme complexe des demandes en eau dans le bassin de

l'Okanagan. Pour reconnaître cette réussite, on a décerné au projet et à son équipe le Premier's Service Award de la Colombie-Britannique pour l'innovation et l'excellence dans la fonction publique en février 2008.

INTRODUCTION

Significant declines in Okanagan sockeye salmon (*Oncorhynchus nerka*) production have occurred during several intervals over the past 50 years in spite of frequent curtailment of both marine and freshwater harvest (Hyatt and Rankin 1999, Stockwell and Hyatt 2003). In Canada, this issue has become a focus for activities of the Okanagan Basin Technical Working Group (COBTWG) that is composed of representatives from Canada's Department of Fisheries and Oceans (DFO), the British Columbia Ministry of Environment (MOE) and the Okanagan Nation Alliance (ONA). In 1998, Douglas County Public Utility District (DCPUD) expressed an interest in working with COBTWG to increase production of Okanagan sockeye salmon. Increased sockeye production constitutes a DCPUD mitigation requirement of their Federal Energy and Regulatory Commission (FERC) license (and, more recently, their Habitat Conservation Plan) associated with operation of the Wells hydropower dam on the Columbia River in Washington State (Bull 1999).

Personnel from DCPUD identified an emphasis in their terms of reference for pursuit of stock enhancement or restoration options that would provide:

- readily quantifiable benefits,
- sockeye salmon production benefits of about 100,000 smolts per annum,
- an economically attractive opportunity relative to alternate approaches,
- potential to achieve regulatory approval by several levels of government, and
- project development and operational deployment within 3 years or less.

The COBTWG acknowledged these requirements and provided additional criteria based on their commitment to the conservation and restoration of Okanagan fisheries resources within an "ecosystem based management framework". These criteria included:

- restoration activities that would provide benefits at the single species level to sockeye and at the ecosystem level to other, high value, indigenous fish species (i.e. provide ecosystem benefits),
- manipulations of fish or habitat that would be amenable to formal risk assessment as one component of benefit-cost analysis,
- application of an adaptive management process for manipulations of fish or habitat (i.e. adaptive management involves adoption of an incremental approach to project implementation, a commitment to assessment and monitoring prior to, during and after project completion and cyclical review of information to make key decisions).

Following review of various project options (Bull 1999) and further consideration of the criteria above, a consensus emerged among COBTWG members by 2001 that a water management option (Fish-and-Water Management Tools Project) was their top priority given that:

- analyses by Summit Environmental (2002) and Hyatt et al. (2001) indicated changes to water management practices had the potential to increase average, sockeye production by roughly 15%,

- costs to achieve this increase were economically competitive with other options (e.g. spawning channel development),
- implementation of the water management option could be achieved within the context of the existing Canada-BC, Okanagan Basin Water Agreement (i.e. no special regulatory approvals were required to implement water management actions contemplated under this option),
- initial development, testing, refinement and deployment of an FWMT decision support system could be completed within 3-4 years,
- provision of decision support tools to key resource managers (i.e. fish and water managers) to improve water management practices for sockeye production would also provide benefits for other high value fish species such as kokanee (*Oncorhynchus nerka*) or rainbow trout (*O. mykis*),
- knowledge of fish-water interactions was sufficiently advanced to support formal risk assessments of potential changes in water management procedures for fish and other water users, and
- alterations to seasonal water storage and/or release practices could be implemented through an adaptive management procedure.

FWMT SYSTEM CONTEXT

The Okanagan River and associated valley-bottom lakes (Figure 1) are managed as a water storage and regulation system, with most of the storage (340 $Kdam^3$) provided by Okanagan Lake as regulated by the control structure at the city of Penticton, B.C. Minor additional storage is provided in headwater reservoirs of smaller tributary streams (principally for domestic and agricultural use) and in Skaha and Osoyoos lakes. Key considerations in the regulation of the Okanagan Lake and River System (OLRS; Hourston et al. 1954) include:

- minimizing flood damage around Okanagan Lake and along the Okanagan River downstream of Okanagan Lake,
- protection of fisheries values (e.g. Okanagan River sockeye eggs and alevins and Okanagan Lake shore-spawning kokanee, their eggs and alevins),
- satisfying domestic and irrigation water supply demands,
- support of recreation, navigation, and tourism by maintaining acceptable water levels and flows for water-craft, docks, launching-ramps, marinas and river-float tourist businesses.

The Okanagan Basin Agreement (OBA; Anon. 1973) emphasized protection of the local sockeye salmon population because it was one of two remaining viable sockeye populations in the Columbia River system, and the only salmon population spawning and rearing principally within the Columbia River basin in Canada. Sockeye salmon spawn in October in the Okanagan River between Vaseux and Osoyoos lakes, principally in the 5 km of river immediately downstream of Vaseux Lake (Stockwell and Hyatt 2003). Egg and alevin development to swim-up occurs between October and early May (Hyatt and Stockwell 2007). Sockeye fry rearing occurs in the north basin of Osoyoos Lake on a year-round basis (Hyatt and Rankin 1999).

Okanagan River flows can affect the sockeye population in the following ways:

- migration to the spawning grounds may be impaired (with resulting pre-spawn mortality and/or reduced gamete viability) as a result of flows that are excessively high or low,
- high summer flows due to melting snow-pack and coldwater input from the Similkameen River into the Okanagan River downstream of Osoyoos Lake reduce water temperatures (Hyatt and Stockwell 2003) which may decrease mortality during upstream migration from Wells Dam pool to Osoyoos Lake,
- eggs and alevins may be impacted (physical damage and inability to survive in the water column) if redds are scoured as a result of flood-control water releases during the pre-emergent incubation period,
- eggs and alevins can be desiccated if incubation period flows are reduced excessively relative to flows during the spawning period,
- seasonal distributions, growth, and survival of sockeye fry rearing in Osoyoos Lake are influenced by temperature and oxygen conditions modified by changes in the quality and quantity of Okanagan River inflow.

In order to mitigate these impacts, the Canada-British Columbia Report on the OBA (Anon. 1973) specified preferred fishery flows for the Okanagan River at Oliver (Table 1).

A review by Bull (1999) suggested that between 1983 and1998, water management decisions frequently departed from compliance with seasonal lake elevation and preferred river discharge levels recommended by the OBA. Discussions with "front line" fisheries and water managers in several FWMT workshops held during 2000-2003 suggested that difficulties in maintaining OBA compliance (Okanagan Basin Study 1974, OBIB 1982) were related to the complexity of balancing fisheries, flood control and water allocation benefits through the year, given large uncertainties in:

- forecasts of annual and seasonal water supplies,
- the exact timing of salmon life history events (spawning, egg incubation, etc.) that control their vulnerability in a particular year to losses from flood-and-scour or drought-and-desiccation processes,
- the magnitude of fish losses likely to be caused by deviations from recommended lake level or river flow ranges (e.g. during flood or drought conditions; Summit 2002),
- risk of "significant property" losses associated with seasonal maintenance of "fish friendly" lake elevation and river discharge levels given either flood or drought events.

FWMT SYSTEM DESCRIPTION

During 2001, the Canadian Okanagan Basin Technical Working Group (COBTWG) initiated a fish and water management tools (FWMT) project (Hyatt et al. 2001) to develop a set of quantitative, decision-support models to reduce uncertainties and improve the basis for water management decisions that influence annual production variations of fish. Creation of a user friendly, decision support system involved several phases of work including:

- a data and information assembly phase (ongoing since 2001),
- a fish-and-water management "business analysis" phase (2001-02),
- a models and information processing tools design phase (2002-03),
- a models and system tools building phase (2003-04), and,
- an operational and refinement phase (2004-present, see Alexander and Hyatt eds. 2005 for complete documentation of the FWMT system).

The resultant FWMT decision support system (Figure 2) and associated software provide a multi-user, gaming environment based on a set of five, coupled, "state-of-the-science" sub-models. FWMT software resides on a common server accessed through standard web-browser technology. FWMT users represent natural resource managers from private industry, First Nations, federal and provincial interests. Detailed descriptions of the design and functional properties of the FWMT system can be found in either the FWMT User Manual (Alexander et al. 2008) or the draft Record of Design document (Alexander and Hyatt eds. 2005). However, briefly here, seasonal variations in precipitation, air temperature, and water temperature serve as common drivers of four biophysical models (Figure 2). These models deal with climate and hydrology interactions, air and water temperature interactions, timing of kokanee spawning and egg incubation success at Okanagan Lake beaches, plus timing and success of sockeye salmon life-history events initiated with spawning in the Okanagan River in mid-October and concluded 14 months later in the winter prior to smolt migration from Osoyoos Lake.

Okanagan water management rules reflecting the contents of the OBA and historic practices of water managers are formalized in a fifth, water-management, "rules" model. The latter facilitates user-specified, choices among seasonal water storage or release options that influence socio-economic and ecological risk factors or events represented within FWMT (Table 2). These occur at several sites distributed from Okanagan Lake and the city of Kelowna in the north to Osoyoos Lake and the town of Osoyoos in the south near the Canada-U.S. border (Figure 1).

The 5 coupled sub-models represent a synthesis of quantitative, cause and effect relationships (among climate, water supply variations, fish, infrastructure and property) used to predict the consequences of seasonal to daily water management decisions for fish and other water users including:

- kokanee production outcomes in the upper watershed (Okanagan Lake),
- sockeye salmon production outcomes in the lower watershed (Okanagan River, Osoyoos Lake) and,
- damage and economic losses associated with urban and agricultural infrastructure and property under flood or drought conditions at riparian locations bordering the Okanagan River and valley bottom lakes.

FWMT can operate on: historical data sets (retrospective-time mode), current data (real-time mode), or on synthetic-futures data (prospective-time mode) to allow resource managers to identify decision options to solve complex fish-and-water management problems. Of particular relevance here, when used in real-time mode, the FWMT system automatically

loads hourly data once a day on Okanagan Lake and River elevations, water temperature, and flows to a database through satellite links from multiple sites (Okanagan Lake, Penticton Dam, Okanagan River at Penticton, Okanagan River at Oliver, etc.). These data drive various sub-models and inform a suite of approximately 50 indicators that help FWMT software users interpret changes in water management risk factors (Table 2). Most indicators are available within the FWMT application during use as model predictions (P) or measured observations (O) (see "Source" section of Table 2). In addition, other diagnostics information may be retrieved through a tab-and-menu design that allows connection of FWMT users to various sources of site-specific indicator observations available through the Internet. Examples are: daily observations of accumulated snow-pack from Mission Creek or Brenda Mine snow-pillow gauges, daily rainfall at Environment Canada meteorological stations in the Okanagan valley, and hourly discharge at Water Survey of Canada sites such as Mission Creek or Inkaneep Creek.

Although most indicators may be routinely accessed from within the FWMT application, a group of at least 14 additional indicators are acquired from sources outside of the application (see "Outside FWMT" section of Table 2). For example, riparian property owners and members of other non-government organizations often communicate their preferences to resource managers about the maintenance of particular seasonal patterns of lake levels or river discharge. Although the OBA specifies seasonal patterns and priorities for their management, regional concerns regarding perceived risks of flooding, drought, loss of fisheries or recreational values do serve as general "pressure indicators" that managers consider when employing particular FWMT scenarios as a basis for specific decisions. Similarly, ongoing field assessment activities, supported by the FWMT project, provide key indicators to verify whether FWMT predictions are a reliable basis for fish-and-water management advice. Thus, seasonal sampling programs to document the timing, duration, or outcome of particular biophysical events (e.g. use of spawning habitat by adult sockeye, timing of sockeye fry emergence, etc.) provide an array of important status and trend indicators. These indicators are used to inform in-season use of the FWMT application (e.g. confirm FWMT prediction that sockeye fry are clear of flood-and-scour risk associated with decisions to increase discharge above egg/alevin scour thresholds). They are also used for post-season assessments of fish-and-water management outcomes (e.g. fish production or economic value gains or losses associated with FWMT use).

FWMT designers recognized from the outset that the complexity of sub-model interactions, numeric output, and scores of potential indicators could limit the utility of FWMT to target users (i.e. front-line, fish-and-water managers). To overcome this problem, system software provides a user-friendly interface that converts complex numeric outputs from model simulations into key performance indicators (e.g. sockeye egg or fry losses; dollar value of insurance claims for flood damage etc.). FWMT performance indicators are expressed in a graphical form that follows a familiar "traffic-light" principal (green = go ahead; amber = exercise caution; red = stop or risk certain damage). The graphical user interface (GUI) and traffic-light indicators largely eliminate requirements for managers to identify precise numeric outcomes to achieve prudent water management decisions (see FWMT User Manual, Alexander *et al* 2008).

FWMT was first put into use in 2004-2005 (Hyatt and Bull 2007). In this report, we review the performance of FWMT during its fourth year of operational use and testing in 2007-2008. The purpose of the report is to provide a record of:

- environmental conditions and selected traits of the subject fish stocks at the start and then throughout the 2007-2008 fish-and-water management year (October 2007 to November 2008),
- the sequence of water storage and release strategies necessitated by climate variations in the Okanagan during the October 2007 through September 2008 portion of the water management year,
- experience with in-season use and testing of the FWMT system,
- advice and management options identified by the FWMT operations team,
- subsequent actions taken by water managers and their outcomes,
- strengths and weaknesses of FWMT as a decision support system, and
- recommendations for changes or refinements to either FWMT or processes supporting its use by the FWMT Operations Team (OT).

In the near term, this information will be used to refine both FWMT application software and OT effectiveness. In addition, this record of management strategy (ROMS) report will contribute to a multi-year assessment due in 2013. The assessment will determine whether deployment of FWMT has contributed to conservation and restoration objectives for the subject salmon populations (Okanagan River sockeye salmon, Okanagan Lake kokanee salmon).

HYDROLOGY AND WATER MANAGEMENT IN THE OKANAGAN BASIN

The Okanagan is a snowmelt-dominated system, with a spring freshet that occurs from April through June, accounting for as much as 90% of the annual inflows (Dobson 2004). By July, the freshet declines and inflows to the system remain low for the summer, fall, and winter. Because of the arid to semi-arid climate in the valley, most summer precipitation evaporates or soaks into the ground and does not contribute directly to surface water flow.

The wide fluctuations between spring and summer flows are tempered dramatically by water regulation. Okanagan Lake receives about 80% of all surface water draining into the Okanagan Basin and has sufficient capacity to store 100% of this inflow in one out of three years and at least 66% of the inflow in eight out of ten years. However, in roughly one in four years, characterized by above average snow-pack, the equivalent of 50% or more of freshet inflows must be released to avoid flooding. Storage during spring runoff reduces the risk of flooding and retains water for release later on, during lower flow periods. With a surface area of 35,000 hectares and a preferred operating range of 1.22 m, Okanagan Lake can store up to 420 million cubic meters of water (Canada – British Columbia Okanagan Basin Agreement, 1974). This capacity is usually sufficient to regulate preferred seasonal levels in Okanagan, Skaha, and Osoyoos Lakes as well as the volume and the timing of flows in the Okanagan River.

Water released from Penticton Dam at the outlet of Okanagan Lake flows south down the Okanagan River through Skaha and Vaseux lakes before entering Osoyoos Lake and then proceeding south for 124 km to join the Columbia River (Figure 1). Several tributary streams join the river between Okanagan and Osoyoos lakes. For most of the year their contribution is relatively small, but during a wet spring, their composite volume can add as much as 57 cms to discharge released from Okanagan Lake (BC Lands, Forests & Water Resources, 1975). A more complete description of the hydrology of the Basin can be found in Glenfir Resources (2006) and Summit Environmental (2009)..

Water storage reduces the risk of flooding, ensures an adequate water supply is available for use in the dry summer months, and provides suitable lake levels for kokanee and river flows for returning sockeye. The decision of how much water to store at any particular time is not an easy one. During spring freshet, the amount of water entering the system can greatly exceed the amount that can be released through the Penticton Dam at the outlet of Okanagan Lake. Therefore, the lake must be lowered before freshet to a level sufficient to store most of the freshet inflows. When inflows exceed the volume of storage plus outflow, tens of millions of dollars worth of real estate may be flooded. On the other hand, if the lake is drawn down too far prior to freshet, resultant summer water shortages will not satisfy both irrigation and aquatic ecosystem needs.

High levels of coordinated effort are needed to: estimate the storage requirement for any particular year, manipulate water levels and flows (e.g. in several lakes and river segments) to match uncertain climatic conditions, alter decisions constantly to keep up with changing circumstances and trade off gains and losses among a wide range of interest groups. An annual operating plan provides targets for lake levels and river flows at various times of the year but the volume of incoming water varies tremendously depending on snow-packs and climatic conditions. This challenges adherence to the annual plan and compliance with fisheries provisions of the Canada-BC Okanagan Basin Water Agreement (Bull 1999). FWMT use facilitates water regulation decisions by providing timely field information and by demonstrating, in advance, likely outcomes of alternate management decisions (Hyatt and Stockwell 2010, Hyatt et al. 2009, Hyatt and Bull 2007).

METHODS

DEPLOYMENT AND IN-SEASON USE OF FWMT

The authority for fish, habitat, and water management decisions in British Columbia is shared between Canada's Department of Fisheries and Oceans (DFO) and the Province of British Columbia's Ministry of Environment (BC-MOE). The Okanagan Nation Alliance (ONA, a First Nation government) is also involved and has a constitutionally guaranteed access to fisheries resources for food, ceremonial and societal purposes. Consequently, fish-and-water management decisions involve the exercise of delegated authority by personnel in each of several federal, provincial and First Nation groups. Participation of key personnel from these groups is essential to the development and routine use of any decision support tools involving fish-and-water management. In consideration of this, the three party Canadian Okanagan Basin Technical Working Group (DFO, BC-MOE, and ONA) formed a FWMT project steering committee to act as a source of "agency" expertise and authorizations for FWMT system deployment, testing, and refinement.

FWMT system use is incorporated into a stepwise pre-season, in-season, and post-season process as follows:

Pre-season Process

1. The FWMT Steering Committee meets in the late fall to confirm Operations Team (OT) lead members and alternates for the upcoming fish-and-water management year.
2. OT members review the management cycle and activities from the previous year and recommend changes or modifications to either the FWMT system (e.g. software, user interface) or OT processes (Hyatt and Bull 2007; Hyatt et al. 2009, Hyatt and Stockwell 2010).

In-season Process

3. The FWMT system is initialized on October 1st with "startup" values (e.g. Hyatt et al. 2008) for year-specific sockeye numbers and biological traits (spawner abundance, start, peak and end spawning dates; sex ratio, magnitude of egg deposition, etc.), and kokanee shore spawner abundance. In the absence of snow-pack and annual water yield predictions prior to February 1st, default all-year average snow-pack and water-yield values are used within FWMT (Alexander et al, 2008) to create a startup base-case to identify an "expected" seasonal water management pattern for Okanagan Lake levels and Okanagan River discharge (e.g. seasonal predictions in Figure 3).
4. The BC River Forecast Centre (RFC) conducts snow surveys at the beginning of each month from January through June with small additional surveys on May 15th and June 15th. Within about a week of the survey, a regional analysis is made of the snow-pack information to provide a prediction of the amount of water that will enter the system for the year. Estimates are provided for an average forecast, a low forecast (1 standard deviation lower than the average), and a high forecast (1 standard deviation higher than the average) for the periods Feb. 1st to July 31st, March 1st to July 31st, April 1st to July 31st, and May 1st to July 31st in a given fish-and-water cycle year.
5. By approximately the 10th day of the month, the Water Stewardship representative receives the inflow forecast from the RFC and enters it into FWMT where it is combined with real-time field information (e.g. daily values for discharge and water temperature imported automatically from Water Survey of Canada hydrometric stations; Figure 1).
6. Between the 10th and 15th days of the month, individual OT members access FWMT through the internet and run a series of simulations or "scenarios" to predict effects of various release and storage patterns on fish (sockeye and kokanee salmon) or other water users (irrigators, recreational boaters).
7. OT members then review risk factors (Table 2) and potential impacts associated with either flood or drought conditions that a given water-management scenario

suggests may affect socio-economic or ecological elements or events throughout the valley.

8. FWMT users initially interpret the likelihood of impacts from a given risk factor or process by examination of whether key indicators (flood risk in Okanagan Lake, sockeye egg-scour risk at Oliver, etc.), portrayed in graphical output from a given FWMT-scenario, exceed hazard thresholds set to warn of moderate (amber) to acute impacts (red).
9. At their discretion, users may then examine supplementary sources of pressure, status and trend indicators (Table 2), accessed from within or external to the FWMT application, to reach an informed opinion about the potential risk and impacts associated with an impending water management decision.
10. Scenario(s), supplementary indicator observations, and interpretive materials are generally shared among OT members via direct e-mail communication or by accessing support information submitted by and for users within the Narratives table accessible within the FWMT application (Alexander et al. 2008).
11. OT members communicate throughout the water year to discuss projected outcomes from the subject scenario(s) and generally, to reach consensus on the preferred flow release plan for the next interval lasting several days to a month. In times of rapidly changing climatic conditions and inflow patterns, OT members run scenarios, confer and then make decisions to change release patterns whenever necessary – sometimes as often as every few days. In relatively benign years, teleconferences may be quite limited, occurring as warranted by climate/water conditions or by request of an OT member.

Post-season process

12. In October or November a "post-season review" meeting is held to consider RFC inflow predictions, inflows observed, water release decisions, and associated outcomes.
13. Following the post-season review meeting, a report of: FWMT scenarios developed, indicators used, advice provided, decisions made, outcomes achieved and recommendations for the future is assembled in a word document to provide an annual record of the performance of both the FWMT System and the Operations Team.

RESULTS

PRE-SEASON MANAGEMENT STRATEGIES

A pre-season FWMT meeting was held in Penticton on November 27, 2007 to review the outcomes of 2006-2007 (see Hyatt and Stockwell 2010) and to discuss the interim outlook and general operational procedures for 2007-2008. Discussion relative to the latter included:

- planning the general, strategic objective for the year (i.e. manage water storage and release decisions such that kokanee and sockeye salmon would be afforded protection from undue lake level or discharge variations without incurring significant increases of collateral damage to other interests from flood or drought events),

- identification of the requirement to store additional water in Okanagan Lake (i.e. keep water levels slightly above the July 29 and Sept. 9 seasonal benchmarks) to facilitate a late summer flushing or pulsed water event to mitigate a temperature-oxygen squeeze affecting the quantity and quality of fish habitat in Osoyoos Lake,
- identification of the FWMT Operational Team for 2007-2008 (Table 3),
- initialization of kokanee and sockeye salmon start-up parameters for Brood Year 2007 (Table 4),
- development and progress of new refinements to the Tool (e.g. develop and implement a new Osoyoos Lake temperature-oxygen squeeze indicator within the FWMT graphical user interface and reports; replace the current constant accumulated thermal unit (ATU) driver for sockeye egg/alevin development with a more temperature sensitive Belehrádek function to improve FWMT predictions of timing of sockeye egg hatch and fry emergence timing).

IN-SEASON DECISIONS

Details regarding in-season events, FWMT Team discussions, flow release decisions, and outcomes are documented in Table 5. Graphic interpretation of decisions, events, and outcomes are identified on outcome charts for key locations in Figure 4.

<u>October - December 2007</u>

The new fish-and-water-management year began October 1, 2007 with Okanagan Lake levels at roughly 10cm below the fall target recommended for kokanee spawning (OBAI 1982; Figure 4A). This low level was a consequence of extreme negative inflows (evaporation, water extraction downstream) combined with sub-average precipitation during the previous summer (Figures 5 and 6). The FWMT-OT identified minimizing reductions in winter lake level as a priority in order to (a) protect beach spawning kokanee from desiccation risk and (b) to ensure the lake would re-fill to meet the summer 2008 targets in the event of low spring inflows. An average snow-pack the previous winter had unexpectedly produced well below average net inflows (Hyatt and Stockwell 2010) and the OT were wary of a similar situation reoccurring in the spring of 2008. Accordingly, spills at Penticton Dam, were reduced from 10 to 4 cms at the end of October (Figure 4B, #1) when sockeye spawning was complete. Releases at Penticton were maintained to yield no less than 5.5cms downstream near Oliver to afford sockeye eggs and alevins protection from desiccation or stranding (OBAI 1982; Table 1; Figure 4D, #1).

<u>January - February 2008</u>

There were no significant weather or hydrological events to warrant changes to the previously recommended discharge pattern throughout January and February. The February 1st RFC inflow forecast of 410 kdam³ (± 20%) to Okanagan Lake was considerably below normal at 74% of the all year average (Table 6). This forecast reflected sub-average snow accumulations in the Okanagan-Kettle Basin in early winter (Figure 7). Weekly precipitation and net inflows to Okanagan Lake remained at about 50% of the all-year average throughout the winter (Figures 8 and 6). Although still early in the water year, existing snow

and weather conditions compelled Water Stewardship to remain cautious of the potential for insufficient water storage for the following the summer and therefore, water conservation remained a top priority. Spill from Penticton Dam was kept at approximately 4 cms through February. This rate ensured nominal decreases in Okanagan Lake level (3 cm drop between Dec.1st and March 1st) and, when combined with downstream, unregulated tributary contributions, provided flows of approximately 5.7 cms at Oliver. This flow strategy presented no risk of desiccation or stranding to incubating kokanee from undue drops in lake level or to incubating sockeye from inadequate flows during the early winter (Figures 4A, #1 and 4B, #1).

March 2008

The March RFC inflow forecast came in at 430 kdam³ (± 21%) which was still just 86% of the all year average (Table 6). This reflected the continuation of sub-average snow accumulations throughout the region (Figure 7). As there was little change to the status of the snow-water indices or to the low inflow pattern to Okanagan Lake, releases continued to be maintained at prescribed minimal rates through the first three weeks in March.

Following the release of the March 1st RFC forecast, there were substantial snow accumulations in the BC Interior such that by the last week of March, snow-water indices were average to above average (e.g. 94% at Brenda Mine ASP, 100% at Mission Creek ASP, 103% at Silver Star MSP, 110% at Trout Creek MSP). The FWMT-OT held a teleconference call on March 25th to discuss the impact of the new snow-pack information and prospective water release plans for the upcoming spring freshet.

March had proved to be unseasonably cold (approaching record low mean monthly air temperatures) and the Environment Canada regional weather outlook stated that conditions would remain much cooler than average through the remainder of the spring. This suggested an increased likelihood of late season snow accumulations and continuation of freezing conditions, particularly at higher elevations (i.e. delay in melt). The OT believed that prolonged, colder temperatures and the possibility of more snow would increase the potential for rapid, high volume melt later in the spring. Additionally, at this time, Okanagan Lake level was approximately 20 cm above the April 1st drawdown benchmark, that is, the level at which the lake could accommodate normal spring inflows. If rapid snowmelt were to occur with the lake level this high, WSD would need to release high volume discharges in order to reduce the risk of lakeshore flooding while risking scour to incubating sockeye or conversely, maintain lower flows to protect sockeye and risk flooding. DFO (Hyatt) directed the OT to shared FMWT scenario 484 (Figure 9) which indicated that spills could immediately be increased to 10-12 cms (currently at 7.2 cms) with additional increases of up to 15-25 cms beginning in mid-May and result in no risk to kokanee. These spill rates would effectively draw the lake down enough to provide room for additional run-off and thus, prevent flooding or the need for scour inducing releases later in the season. Water Stewardship (Anderson) agreed that this strategy was appropriate and proposed to initiate 10 cms releases at Penticton Dam immediately. Additionally, WSD was confident that this moderate water release strategy would provide ample opportunity to revert to water conservation mode if the spring run-off resulted in considerably lower volumes than anticipated. BC MoE (Askey) was satisfied that the additional drawdown posed no threat to kokanee as they were nearing completion of emergence (Figure 9A).

Following the conference call (March 28th), WSD (Anderson, Symonds) reassessed the situation by comparing the current level of Okanagan Lake against the all year average for the same time period. They found this year's level to be slightly above the all year, upper 25th percentile (Figure 10). Therefore, given the projection of near normal run-off, WSD felt it would be prudent to increase recommended releases from 10 cms to 18 cms beginning April 1st in order to draw the lake down even more by early April. However, flows at Penticton would again be reduced if additional unregulated tributary inputs downstream near Oliver brought flows close to the sockeye, redd-scour threshold (28 cms). DFO agreed to the higher spill rate as it would help avoid any necessity for WSD to initiate scour-inducing flows on alevins later in April if tributary inputs peaked suddenly.

April 2008

As of April 6th, the flow increases outlined above had not been initiated. DFO (Hyatt) expressed concern that if the lake was not drawn down soon, scour inducing release rates (>28 cms) would be required prior to completion of sockeye fry emergence. The ongoing, cooler than average temperatures would not only delay snowmelt but also delay the rate of sockeye development to fry emergence. Field sampling during the same week confirmed that fry emergence had not yet begun (Figure 11). WSD (Cunningham) responded that they had delayed the increases for a week at the request of the ONA so that crews could complete in-stream fieldwork. As work was complete, releases were adjusted the next day (April 7th). Ultimately, Penticton Dam releases were set slightly lower than the recommended 18 cms (15 cms at Penticton;15.4 at Oliver) when the updated, April RFC inflow forecast came in at 390 ± 90 kdam³ or approximately 82% of average (Table 6). DFO supported the new releases as several FWMT scenarios using this water release plan indicated there was adequate room in the lake to handle spring run-off given the new inflow forecast, even if it turned out to be a late season, compressed melt.

FWMT identified 100% kokanee emergence at April 8th. "Kokanee friendly" lake level objectives were met for 2007-2008 water year as indicated by the solid green performance bar (Figure 4A).

By mid-month, the situation had changed significantly such that the OT was once again considering reverting to a water conservation strategy. DFO (Hyatt) posted a narrative and updated Scenarios to the FWMT website outlining current conditions and rationale for decreasing spill at Penticton Dam (Table 5, Bullet #4; Figure 12). A review of the hydrological conditions indicated a snow-pack and water yield from melt that could create a situation very similar to the spring of 2006-07. At that time, snow-water indices and the RFC forecast promised normal to above normal inflows to Okanagan Lake. However, the anticipated run-off did not materialize which necessitated a rapid switch from a water release to a water conservation strategy relatively early in the season; however, even with reduced releases the lake still did not reach full pool (Hyatt and Stockwell 2010). Okanagan Lake was currently about 1.5 cm below the level observed on the same date in 2007. Similarly, net inflows from tributaries had been strongly sub-average since early January and less than 50% of average in March and April suggesting 2008 might be another dry year (Figure 8).

Given a near average snow-pack, sub-average inflows, and level of Okanagan Lake, there appeared to be little imminent risk of a flood event. Therefore, Hyatt suggested decreasing flows in the short term from 15 to10 cms at Penticton Dam in order to stabilize Okanagan

Lake at the current level until there was a better idea of the expected water yield off the current snow-pack. WSD (Anderson) concurred with this strategy and dropped water releases the following day to 10 cms.

May 2008

By May, conditions had reversed again. The FWMT-OT held a teleconference May 1st to review current water supply conditions and discuss possible water release strategies for the impending spring freshet. Late April snowfalls and substantial delays in snowmelt had made it extremely difficult for the OT to predict timing and volume of inflows to Okanagan Lake and thus, estimate appropriate discharge rates. April 2008 was the coldest on record (Environment Canada, 2008). Generally, in the Southern Interior, transition from snow accumulation to snow melt occurs by late March at low elevations and by mid-April at higher elevations. However, in 2008 the cool spring led to a continued increase in snow-pack at higher elevations (e.g. Mission Creek ASP; Figure 7A) and a 3 week delay in the onset of snow melt at lower elevations (e.g. Brenda Mine ASP; Figure 7B). This was observed as increases in snow-water indices such that the May 1st, overall Okanagan Basin index was 103% of average - a substantial increase from the April 1st estimate of 93%.

The May RFC forecast was not available at the time of the call but given the current snow-pack, the forecast was expected to be above April's estimate of 390 kdam³. WSD (Anderson) expressed some concern that the extended delay in snowmelt had the potential to create some flood risk by way of a compressed, high volume freshet. Flood risk would be elevated if air temperatures suddenly reached seasonal norms and/or heavy rain on snow events occurred.

Weekly field sampling for sockeye fry in the Okanagan River confirmed that emergence had peaked around April 22 (Figure 11). Peak abundance observations[1], FWMT model predictions (based on a constant ATU threshold for emergence), and independent Belehrádek (allows for a variable ATU threshold for emergence) calculations based on spawning ground water temperatures, all indicated sockeye emergence should reach 100% by May 5 to 8. DFO (Hyatt, Stockwell) were confident that sockeye fry would be safe from scour threat by the end of the first week in May if high inflows necessitated ramping up water releases at Penticton Dam. Given these observations, the OT advised that water release strategies should shift from a fisheries focus (sockeye scour and desiccation issues) to flood prevention. Releases were to be increased to 15cms with additional increases anticipated over the next four weeks as inflows to Okanagan Lake increased.

Towards mid- month, snowmelt finally began in earnest as air temperatures increased rapidly, reaching highs of >30°C. Inflows to Okanagan Lake increased dramatically (Figure 8); however, releases from Penticton Dam were held below 10 cms to accommodate rapidly escalating inflows from unregulated tributaries downstream (Figures 4B, 4C and 4D; #6).

Direct observations from field surveys during May confirmed the completion of sockeye fry emergence (98%) near May 9th (Figure 11). Overall, "sockeye-friendly" flow objectives were met for the incubation portion of the 2007-2008 fish-and-water management cycle. The

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[1] Fry emergence is generally considered to be complete 8-14 days after the peak has been observed (Hyatt and Stockwell 2007).

amber alevin bar through February and March (Figure 4D) cautions of potential stranding and desiccation risk to motile alevins. In fact, the actual risk to stranding of alevins was low as flows near Oliver remained quite consistent throughout that period.

June 2008

By the first week in June, low elevation snowmelt was complete and high elevation snow-packs were diminishing (e.g. Mission Creek ASP had receded by about 30%). Unregulated tributaries had peaked and were starting to decline (Figure 4C, #9 and 4D, #9). At this time, the FWMT-OT was confident that the danger of flooding was over and higher inflows through June would be manageable. Following the exceptionally cool spring and high May inflows (Figure 8), DFO (Hyatt, Stockwell) were not anticipating a temperature-oxygen squeeze in Osoyoos Lake in the summer of 2008. Still, FWMT was projecting water supplies that were sufficient to allow a pulsed water release (25-35 cms for 10 days to 2 weeks) in order to mitigate a squeeze event should one begin to develop (Figure 13).

By the second week in June, a series of weak frontal systems moved through the region generating additional snow at higher elevations and high volume rainfall (>30 mm) in the valley. The amount of rain significantly advanced the projected timing to full pool (i.e. within the week). WSD (Anderson) informed the OT that he intended to apply an aggressive water release strategy to ensure the lake flood benchmark would not be surpassed. Spills from Penticton Dam would be made in increments, reaching 50 cms by June 11th (Figure 14). Hyatt and Alexander reviewed the aggressive release scenario and suggested lower spills (i.e. 30-40 cms) as Okanagan Lake was already showing signs of cresting without reaching full pool by the June 24th target (Figure 15). With careful monitoring of weather conditions and lake level response to inflows, flood risk would not be considered a problem. As well, additional water could be stored in Okanagan Lake to accommodate a late summer pulse release of water to mitigate the Osoyoos temperature-oxygen squeeze if it showed signs of developing. WSD agreed to this strategy and set spills at approximately 37 cms; a tentative spill schedule to the end of July was sent to the OT (Table 5, #9).

July 2008

Unprecedented numbers of adult sockeye salmon returned to the Okanagan River in the summer of 2008 (Figure 16). The total count of 165,334 fish passing Wells Dam on the Columbia River was the highest number ever recorded (previous record was 113,000 in 1967). The presence of this remarkable abundance of fish in the Okanagan River triggered growing interest from the public such that fish and water managers were beginning to field queries and concerns about the sockeye and possible detrimental effects of high water temperature and low river flows. There were some suggestions that increasing water releases at Penticton and Zosel dams might provide cooling flows in the lower Okanogan River (Washington State) and thus, provide tolerable temperatures to migrating sockeye. Additionally, WSD had hoped to initiate annual release reductions (to approximately10 cms) to promote water conservation and storage in Okanagan Lake required for summer water allocations.

DFO (Hyatt) provided clarification to WSD based on the following information. Behavioural investigations have shown that adult sockeye will stop their migration as water temperatures

climb and exceed 21°C. They will seek refuge in cooler water and resume migration once falling, seasonal temperatures drop below 21°C (Hyatt et al. 2003). In the lower Okanogan River (U.S.), inflows from the Similkameen River often have a cooling effect on early summer temperatures (i.e. high volume snow melt); however, flows originating from the upper Okanagan River do not have the same effect because out-flowing water consists of warm, epilimnial spill from Osoyoos Lake. Increasing water releases from the Penticton and/or Zosel Dams would not have a cooling effect on lower river temperatures and thus could not help prevent a delayed entry of adult sockeye into the Okanogan River. If sockeye cannot pass the temperature barrier in the lower Okanogan River, they will hold in the Columbia River at Wells pool where temperatures average approximately 18°C during the summer and wait until the Okanogan begins to cool.

At the time sockeye were observed in the upper Okanagan River, water temperature was climbing and had reached approximately 20°C. Observations from past years indicate that despite the warm summer temperatures, early migrants tend to swim up as far as McIntyre but will then drop back downstream once the river hits 21°C to hold in the cooler, deeper waters of Osoyoos Lake until early fall. As above, increasing releases from Penticton Dam would merely introduce warmer epilimnial waters from Okanagan Lake to the river. Additionally, water temperature has the tendency to increase over distance due to the influence of solar radiation, so higher spills would not contribute to a cooling effect further downstream.

Accordingly, DFO advised water management to continue to focus on water conservation for late summer irrigation and domestic requirements and for mitigation of a possible temperature-oxygen squeeze in Osoyoos Lake. The recommendation was to reduce water releases at Penticton Dam to 10 cms. This discharge rate is well within the range (8.5 - 12.7 cms) recommended for adult sockeye migration and would have no unforeseen impacts on the fish. As of July 12th discharge at Penticton Dam was reduced to 10 cms (Figure 4B, #10).

August - September 2008

As is typical of the southern interior, summer in the Okanagan Basin was hot and dry. A general pattern of sub-average precipitation persisted through June (75% of normal), July (25% of normal), and into early August. Net water inputs from tributaries to Okanagan Lake assumed negative values (i.e. extractions and evaporative losses greater than inputs) by the week ending July 8th, which was approximately 4 weeks earlier than average (Figure 8B). Net inflows to Okanagan Lake remained sub-average through to the end of October. Water releases at the Penticton Dam were maintained after July 12th at 10 cms to conserve water. By early August, it was apparent to fish managers that there was an increasing likelihood of significant reductions in juvenile rearing habitat[2] caused by the development of late summer temperature-oxygen squeeze in Osoyoos Lake - particularly if water releases continued to be maintained at low rates.

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[2] Optimal juvenile rearing habitat is the depth interval at which water temperature is <17°C and dissolved oxygen concentration is >4ppm. The severity of a squeeze event is indicated by the level of convergence of the 17°C and 4 mg/litre oxygen isopleths (Hyatt et al. 2009).

Summer in-lake sampling included numerous, seasonal vertical profiles of temperature and oxygen concentrations in Osoyoos Lake. Over the summer, profiles identified the progressive descent of the 17°C isopleth such that juvenile sockeye were restricted to depths below 13 m by August 11th (Figure 17). At this date, the 4ppm O_2 isopleth remained stable near the bottom, still allowing juvenile sockeye access to deeper, cooler water. However, the onset of reduced oxygen concentrations at shallower depths was apparent in the rapid ascent of the 6 ppm O_2 isopleth from 48 m to 16 m (Figure 17). Previous experience suggested that once oxygen depletion begins to develop in the hypolimnion, progress towards hypoxia is rapid and an acute squeeze can develop within a very short time period (i.e. less than 1 week; Hyatt and Stockwell 2010). A teleconference between fish and water managers was held to discuss the potential to mitigate the pending squeeze with a high volume, pulse release of water from Penticton Dam. The objective of a pulsed discharge is to flush organic matter from the surface water of Osoyoos Lake, expecting that this will reduce organic loading and biological oxygen demand in the deeper waters of the lake. Multiple FWMT scenarios (e.g. Figure 18) suggested that persistent flows of less than 15 cms through late August and September would induce a temperature-oxygen squeeze. Conversely, additional scenarios also demonstrated that a controlled pulse release of water (30-35 cms for 3 weeks) could effectively flush the epilimnial waters of Osoyoos Lake and reduce early onset, duration or magnitude of squeeze events (e.g. Figure 19). Okanagan Lake level was approximately 8 cm above the late summer benchmarks (Figure 4A, #11) and FWMT-OT members agreed that there was sufficient water available to make a pulsed-release feasible without (a) compromising water allocations for the remaining summer and fall, (b) drafting the lake below the preferred fall benchmark for kokanee spawning, or (c) impacting flow requirements necessary for adult sockeye migration and spawning. Consequently, WSD increased releases at Penticton Dam from 11 to 30 cms on August 23rd and held flows at that rate until September 22nd (at which time flows were cut back to 15 cms). Temperature and oxygen profiles taken through the remainder of the summer and fall indicated a retreat of the 6 ppm O_2 isopleth in association with this pulsed water release (Figure 17).

The 17°C isopleth began ascending towards the surface in conjunction with autumn, night cooling around September 15th. The 4ppm O_2 isopleth made a brief ascent to 38m followed by a rapid retreat in mid-October. Condition and volume of juvenile sockeye rearing habitat in Osoyoos Lake remained favourable throughout the entire summer (Figure 4E and Figure 17). This was just the 2nd year in the most recent 12 years of sampling that a pronounced temperature-oxygen squeeze did not materialize in Osoyoos Lake.

MODIFICATIONS TO THE FISH-AND-WATER-MANAGEMENT-TOOL MODEL IN 2007 - 2008

FWMT has continued to undergo testing and refinement of software since its initial deployment in 2004. Since then, there have been numerous modifications to improve the user interface, model navigation, graphic output displays, and communication among operators (Hyatt and Stockwell 2010, Hyatt et al. 2009, Hyatt and Bull 2007). However, Hyatt and Stockwell (2010) identified two important weaknesses in the FWMT user interface that remained unresolved at the end of the 2006-2007 water year. The first was that, FWMT outputs, intended to inform users about the development and severity of temperature-oxygen squeeze events in Osoyoos Lake, have been difficult for most users to interpret because the influence of temperature and oxygen conditions on fish habitat was not obvious

in the existing FWMT graphical presentation (see Hyatt and Stockwell 2010). Moreover, once a temperature-oxygen “squeeze” triggered an acute habitat state-change (red hazard bar) within FWMT for sockeye fry rearing in Osoyoos Lake it remained “locked” in that state. This conflicted with an intuitive understanding that seasonal improvements in river discharge and lake temperature should reverse “squeeze” conditions (i.e. FWMT hazard indicators should revert to amber or green) . Consequently, the display for this FWMT indicator provided little insight to assist users with determining seasonal, flow release strategies to help mitigate a squeeze event. The second was that, in the several years since the deployment of FWMT, significant discrepancies between model predictions and observed timing to 100% sockeye fry emergence appeared to be associated with violation of an assumed constant rate of day-degree accumulation to reach the threshold for emergence. The source of this discrepancy between predicted and observed fry emergence appeared to be the well known phenomenon that, under either unusually warm or cold conditions, developmental rates of salmon eggs and alevins depart sufficiently from their normally linear association with temperature to introduce errors into hatch and emergence predictions based on constant ATU thresholds for these events. During years of high inflows to Okanagan Lake, accurate prediction of fry emergence is critical in order to provide water managers with sufficient leeway to balance off risk of flood induced damage along shoreline properties with risk of premature scour losses of sockeye alevins and pre-emergent fry. Both issues were resolved and solutions implemented within FWMT software in 2008 as follows..

Osoyoos Lake Temperature-Oxygen Squeeze Revisited

Sockeye fry rearing in Osoyoos Lake are exposed to extreme seasonal changes in physical and biological conditions. Osoyoos Lake tends towards mesotrophic conditions that place it near the upper end of the range of productivity for sockeye nursery lakes (Hyatt and Rankin 1999). Relatively high nutrient concentrations, primary productivity and standing crops of zooplankton dominated by Daphnia species, the preferred prey of sockeye, all contribute to spectacular first year growth by fry. However, the conditions producing rapid growth rates operate on a “knife-edge” and can contribute to very poor survival conditions in the fall.

The development of high temperatures (> 17°C) in the epilimnion and of hypoxia in the hypolimnion (< 4 ppm O_2) during the late summer to fall interval have a major influence on the quantity and quality of limnetic habitat that is suitable for rearing by juvenile sockeye. Under these conditions, field observations have demonstrated that both the south and central basins of Osoyoos Lake become wholly unsuitable for occupation by juvenile sockeye through most of the late spring through fall growing season. Thus, the north basin of Osoyoos Lake appears to support virtually all of the fry-to-smolt production originating from Osoyoos Lake each year, but even this portion of the lake is subject to a late-season, temperature and oxygen “squeeze”.

Recent analysis (Hyatt et al. 2009) suggests that variations in these conditions are severe enough in the north basin in some years to reduce the volume of habitat that is useable by sockeye to virtually zero. Under analogous conditions that persisted for several weeks in the central basin of Osoyoos in 1998, Hyatt and Rankin (unpublished data) estimated the loss of more than 75 % of the small population of juvenile sockeye that was resident in the basin at the time. During 2003, when minimum useable water volume (MUWV) was reduced to zero at station 1 and to 23 ($x10^6$) m^3 at station 2, almost 60% of the North Basin juveniles disappeared between 26 May and 20 September.

To account for this phenomenon, the FWMT sockeye sub-model invokes a density-independent mortality rate applied to sockeye fry given the occurrence of extreme combinations of temperature and oxygen conditions (i.e. "squeeze events") experienced while rearing in Osoyoos Lake. Specifically, the MUWV (in millions m^3) likely to develop in the north basin Osoyoos Lake during mid-to-late summer is assumed to be a function of the cumulative inflow to Osoyoos Lake from Okanagan River in the months of August and/or September according to the equation:

$$MUVW = 9.82\ MI - 80 \quad (n = 9,\ r^2 = 0.65)$$

Where: MUVW is the minimum useable volume of water for sockeye fry rearing observed during the August 1 – Nov. 30th interval each year and MI is the mean daily inflow (in cms) of water into Osoyoos Lake during August and September (see Alexander and Hyatt 2013 for additional details).

The predicted MUWV value is arbitrarily assigned to occur on September 16th of a given year because there is currently no way to identify *apriori* the precise date on which MUWV will occur in a specific year (historically the MUWV has always occurred between Sept. 1st and Oct. 16th). If the predicted MUVW = 0 then its position is arbitrarily superimposed on the depth position of the 17°C isotherm on Sept. 16th (i.e. by definition an acute "squeeze event" occurs when Osoyoos Lake is devoid of any volume of water that is < 17°C and > 4ppm O_2). The depth for various non-zero values of MUWV are obtained from an FWMT internal lookup table where entries for the depth of the 4ppm O_2 isopleth have been calculated to satisfy the predicted MUVW (from the equation above) on Sept. 16th given that the 17°C isotherm occupies a fixed position of 13.5 m (*i.e.* the all-year mean). Daily positions of the 4 ppm O_2 isopleth between Aug. 1st and Sept. 16th and again from Sept. 16th to Nov. 1st are then determined by linear interpolations between specific values provided on: July 31st (observed all-year average), Sept. 16th (predicted MVUW) and October 31st (observed all-year average).

A green hazard is assigned on any day for which the 4 ppm O_2 isopleth is $\geq$ its all-year average position in the Osoyoos Lake water-column. An amber/yellow hazard is assigned on any day for which the 4 ppm O_2 isopleth is > 21.5 m but < than its all-year average value. A red hazard is assigned on any day for which the 4 ppm O_2 isopleth is < or = 21.5 m. Days that are associated with the red hazard squeeze risk are assigned an elevated density independent mortality rate of 0.0327 i.e., a constant density-independent survival rate within the FWMT sockeye sub-model equal to 0.9673 (see Figure 18c example of the new form of graphical output for the FWMT "squeeze" indicator).

Implementation of the Belehrádek Equation for Sockeye Development

The timing discrepancies identified between model and real-time predictions for 100% sockeye hatch and emergence in past years may be attributed to the way the sockeye sub-model dealt with daily water temperature and its influence on sockeye embryo development. Originally, in order to calculate developmental stage timing, the model incorporated the accumulated thermal units (ATUs) method. This particular method assumes that the

developmental rate of salmonid embryos varies lineally with temperature such that hatch and emergence timing is calculated simply by summing thermal units (daily mean temperatures) accumulated throughout the incubation period (i.e. 100% hatch = 595 ATUs while 100% emergence = 875 ATUs). However, research suggests that developmental rates become markedly curvilinear as developing embryos physiologically compensate for warm and cold extremes in water temperature (Brannon 1987, Beacham and Murray 1990). In particular, the rate of change in development is greatest at the colder end of the tolerable temperature range. For example, in sockeye salmon, Brannon (1987) found developmental rate compensation of up to 800% occurs as incubation temperatures fall from 4 to 0°C. Conversely, development slowed down considerably as temperatures increased above 5 °C. Accordingly, low water temperatures require fewer ATUs to reach 100% hatch or emergence while higher temperatures require more ATUs (see Hyatt and Stockwell 2010 for more detailed discussion).

The log-inverse Belehrádek formula accounts for the non-linear effects of incubation temperature on development and is considered to be a more reliable method to predict hatch and emergence timing, particularly in habitats where temperature is highly variable throughout the incubation period (Beacham and Murray 1990). In the Okanagan River, mean daily temperatures can range from 0 to 5°C in the winter and from 3 to 14°C in the fall (post spawn) and spring (pre fry emergence; Stockwell et. al. 2001). In 2008, a new algorithm incorporating the log-inverse Belehrádek method was incorporated into the FWMT sockeye incubation sub-model to improve the accuracy of prediction to 100% hatch and emergence (Equation 1; Beacham and Murray 1990).

Equation 1: $\log_e D = \log_e a + b \log_e (T - c)$, where:

D = observed hatching or emergence time after fertilization
T = observed mean temperature, and
a, *b*, and *c* are fitted coefficients (for development stage specific to species)

Sockeye Hatching: a = 8.734; b = -1.589; c =-7.067

Sockeye Emergence: a = 7.647; b = -1.134; c = -3.514

The sockeye sub-model now uses the Belehrádek method to calculate and predict sockeye egg hatch and fry emergence. However, both the ATU and Belehrádek predictions can be found in the "sockeye emergence timing" report for users to compare the outcomes of each approach.

As heat storage in large lakes provides a buffer, water temperatures in Okanagan Lake remain stable even during extended periods of sub-zero air temperatures. Consequently, the current FWMT kokanee sub-model assuming lineal ATU accumulation regardless of temperature range, works well to predict kokanee hatch and emergence times and remains in the sub-model as the method to determine kokanee developmental timing.

Other Modifications

A minor modification was made to the depiction of unregulated tributary inputs in the graphical displays for (a) Okanagan River at Okanagan Falls and (b) Okanagan River at Oliver. Originally, the real-time and forecast inputs were indistinguishable (i.e. identified as a single, continuous brown line) which caused some confusion when interpreting the graphical outputs, particularly for new FWMT users. Display coding has been amended so that now, real-time tributary inputs are clearly displayed as a black dashed line, while predicted inputs are displayed as a blue dashed line.

POST SEASON ANALYSIS

The first six months of the 2007-2008 water year were relatively benign, with no significant weather or hydrological events that warranted major discussions by the FWMT-OT. WSD was compelled to maintain a minimum water release strategy for water conservation purposes. This year followed on the heels of an extremely dry year, which had been additionally confounded by the lack of run-off from a normal snow-pack (Hyatt and Stockwell 2010). Then, the fall and early winter of 2007-2008 consistently produced sub-average snow-packs and low inflows to Okanagan Lake (Figures 7 and 8). These circumstances led WSD to be particularly cautious of the potential for a long term drought situation developing. All team members agreed that water conservation in Okanagan Lake was a top priority in order to ensure sufficient water storage for summer irrigation and fisheries requirements. Spills from Penticton Dam were maintained at approximately 4 cms and this resulted in the desired, minimal decrease in Okanagan Lake level (3 cm drop to March 1st; Figure 4A, #3). With additions from unregulated tributaries, flows downstream near Oliver remained at 5.5 to 6.0 cms, adequately protecting incubating sockeye eggs and alevins from risk of desiccation.

As spring approached, the FWMT-OT shared and discussed scenarios much more frequently as circumstances rapidly alternated between the need for water conservation and the need to accommodate run-off from a potentially rapid, high volume freshet (Table 5). April and May proved to be abnormally cold and saw the arrival of substantial, late season snow accumulations at ASPs as well as up to four weeks delay in spring melt (Figure 7). The team was initially concerned that a late, compressed melt or a rain on snow event could trigger high inflow volumes resulting in lakeshore flooding and/or scour of sockeye alevins and fry. The OT agreed on a strategy of increased releases from Okanagan Lake in order to draw it down and create the capacity for high inflows. However, shortly after this decision was made, snow and hydrological conditions were re-evaluated and appeared similar to the dry spring of the previous year when WSD was forced into water conservation mode when the spring freshet did not materialize. Water releases from Penticton Dam were again reined in until more specific information became available regarding timing and volume of the freshet. Normally, high elevation snowmelt should have materialized by mid-April; however, accumulations continued to build until mid-May (Figure 7). In time, WSD became increasingly concerned about rain on snow or elevated temperature events that had the potential to cause flooding around Okanagan Lake. By this time, sockeye emergence was nearly complete; therefore, the OT agreed that release strategies should be placed solely in the hands of WSD to focus on flood prevention.

The possible threat of reduction to juvenile sockeye rearing habitat in Osoyoos Lake became apparent in early August as the 6 ppm O_2 isopleth rapidly ascended off the bottom

and converged with the 17°C isopleth at a depth of approximately 15 m. Although 4 ppm defines the critical oxygen concentration for juvenile sockeye, once oxygen depletion begins to develop in the hypolimnion (as indicated by the 6 ppm O_2 isopleth), the progress towards severe hypoxia is rapid, and an acute squeeze can develop within a very short time period. At the request of DFO, WSD provided a pulsed flow (30 cms for 3 weeks) which successfully initiated recession of the low oxygen water, averting the development of a temperature-oxygen squeeze in Osoyoos Lake (Figure 4E).

Overall, FWMT-OT participants were successful in developing informative FWMT scenarios to facilitate discussion and subsequent water management decisions that prevented any significant losses of: kokanee from desiccation in Okanagan Lake (Figure 4A), sockeye eggs and alevins in the Okanagan River, or fry rearing in Osoyoos Lake (Figure 4D and E). Water releases at Penticton Dam met all seasonal benchmark for Okanagan Lake and River, avoiding flooding, satisfying lake level and discharge requirements for recreation, domestic and agricultural water supplies (Figure 4).

Finally, several FWMT users who were fairly new to the project requested a training session to better understand in-season operation of the model and interpretation of the output reports. On February 25, 2008 a one day, training workshop was conducted by Clint Alexander of ESSA Technologies and attended by eight people from the ONA, BC MoE Water Stewardship Division, and BC MoE Fish and Wildlife Department. Participants were able to complete at least one "test" year within the FWMT training-mode module under Clint's guidance. All came away with a much clearer understanding of how to use the model and its value to balancing water releases at Penticton Dam with kokanee and sockeye requirements in the Okanagan basin.

DISCUSSION

After four years of in-season application, FWMT is firmly embedded in standard operating procedures for the Okanagan Lake and River System (OLRS). Water and fisheries personnel have come to rely on the model to produce and share scenarios for discussion, particularly during times of uncertain or rapidly changing climate conditions. This routine allows the OT to achieve understanding and agreement on the best possible water management strategies.

Much of water year 2007-2008 was relatively unremarkable with respect to weather or hydrological events that could impact water management objectives (e.g. avoid flooding, ensuring water supply for domestic or agricultural water withdrawals) or fisheries management objectives (e.g. avoid scour or desiccation of sockeye eggs and alevins, avoid de-watering kokanee eggs). Nonetheless, participating agencies regularly shared FWMT scenarios in order to achieve a consensus on release strategies that would benefit all (Table 5). The FWMT-OT discussed (phone, e-mail, or in person) all modifications to Penticton Dam release rates throughout the kokanee and sockeye incubation periods. Although the frequency of discussions dropped off following completion of sockeye emergence, WSD and DFO personnel remained in contact, focusing on the need to conserve surplus water in Okanagan Lake (i.e. keep levels above summer benchmarks). Additional water storage was successfully achieved such that water management was able to fulfill DFO's request for a

late summer pulsed-release of water in order to deflect a temperature-oxygen squeeze event in Osoyoos Lake.

Four years of real-time operation have provided the OT with another important resource for planning release strategies. FWMT team members can access records of decisions, rationales behind them, and outcomes for each water management year (e.g. Narrative Tool in FWMT, Records of Management Strategy, personal records).These historic narratives provide valuable guidance to shape decisions in a current operating year. For example, recalling the lack of run-off from a normal snow-pack in 2007 and comparing similar conditions (snow-pack, lake level, flow decisions, etc.) to 2008 influenced the OT to reverse their decision on increasing Penticton Dam releases in 2008. In the end, the result from this decision was inconsequential thus illustrating how quickly water supply conditions can shift from risk of freshet flood to risk of drought in some years and the value of FWMT in providing updated scenarios that reflect such changes in a timely fashion. The FWMT program has operated for enough years that most significant events (e.g. drought, flood, ice on the spawning grounds, etc.) and the collaborative decisions on how to handle them have been documented. Furthermore, these records will be an important resource to new managers who face a steep learning curve associated with the challenge of balancing water storage and release decisions to satisfy numerous requirements throughout the OLR System.

From the initiation of kokanee spawning in fall through to emergence of fry in spring, water levels in Okanagan Lake were stabilized through low releases at Penticton Dam. Water levels remained well within the low risk zone for incubating kokanee eggs and alevins and consequently, there were no significant losses of eggs or alevins prior to spring emergence due to dewatering (Figure 4A). Similarly, despite low, water conservation releases at Penticton Dam through to early spring, WSD ensured that requisite flows (>5 cms) were maintained on the sockeye spawning grounds such that sockeye eggs and alevins were never subjected to desiccation risk from dewatering of redds. An unusually cold spring and extremely long delay in snowmelt eliminated the threat of sockeye losses from scour events as fry had completed emergence two weeks prior to peak run-off - the time when WSD substantially increased releases at Penticton Dam to prevent flooding (Figure 4D, #6). Additionally, having focused on early water conservation, managers were well prepared to execute a pulsed flow of water in order to alter the development of a severe temperature-oxygen squeeze that threatened to degrade juvenile rearing and adult holding habitat in Osoyoos Lake. Ultimately, there were no significant losses of sockeye due to drought and desiccation events, flood and scour events, or reductions in juvenile rearing habitat. Water Stewardship was able to achieve satisfactory lake levels and river flows to meet fisheries requirements as well as those for recreation and domestic and agricultural water withdrawals throughout the water year.

New graphical output to identify the risk of temperature-oxygen squeeze events in Osoyoos Lake were provided to OT participants for the first time in summer 2008. Although user-induced differences in FWMT scenario output regarding squeeze events generated some initial confusion (Table 5, Sept. 19th commentary), the general consensus by the end of the 2007-08 fish-and-water year was that the new graphics indicator provided timely and intuitively satisfying portrayal of the risk of squeeze events. For example, multiple FWMT scenarios generated in early Aug. suggested that a squeeze event was likely to develop and become critical by late summer (e.g. Fig. 18c). Direct observations from field surveys of

temperature and oxygen conditions at depth during this same period (Fig. 17) reveal that a squeeze event began to develop in early August, became acute by late August but began to dissipate by early September coincident with a pulsed-release of water from Penticton Dam.

New coding to incorporate the Belehrádek sockeye developmental equation into FWMT noticeably improved the estimates of 100% sockeye hatch and emergence dates. In scenario 498 run on June 2 (Figure 14), the model was still estimating developmental timing by using the simple ATU method. In this scenario, the egg and alevin hazard bars indicate that hatch and emergence reached completion during the weeks ending April 8th and May 20th, respectively. However, a scenario run in September 2008 (Figure 5D) following the coding change, identified timing for 100% hatch and emergence as March 4th and May 7th, respectively. ONA field crews conducted hydraulic sampling surveys of redds on the sockeye spawning grounds December through March. Results from these surveys indicate that the number of live eggs found in redds was reduced to zero while the numbers of hatched alevins increased significantly between February 27th and March 6th (Figure 20). Fyke net sampling for emergent fry in the Okanagan River during April and May determined that emergence peaked near May 22nd and was virtually complete (98%) by May 9th (Figure 11). Thus, the ATU method suggested that incubating eggs could be at risk to scour or desiccation a full month longer than field observations determined. Additionally, the same method estimated sockeye hatch as nearly two weeks later than observations from field sampling found. By contrast observed egg hatch and fry emergence times were very close to the Belehrádek derived dates of March 4th and May 7th. Sockeye fry emergence and the timing of peak freshet in the Okanagan are often virtually coincident. Consequently water managers are challenged to precisely manage the timing of increased spill at Penticton Dam to balance the risk of an early decision resulting in scour-induced losses of pre-emergent sockeye fry versus a late decision resulting in flood losses for riparian property owners. Under these conditions, improvements in information regarding the precise timing of sockeye egg-hatch and fry emergence has exceptional value in meeting this challenge. Given this perspective, FWMT predictions of egg hatch and fry emergence provided by the non-linear, Belehrádek formulation are a marked improvement over those from the simple lineal formula it replaced.

FWMT has enabled managers to provide "fish friendly" flows that are expected to reduce density-independent losses of sockeye eggs, alevins, and fry due to scour or desiccation events and lake, rearing-habitat losses. Increased adult escapement combined with reductions in density-independent loss events have been accompanied by significant increases in the all-year average of sockeye smolt production since the initial deployment of the FWMT system. In 2008, more than 135,000 adult sockeye of Okanagan origin returned to the Columbia River representing the largest returns of this stock in over 30 years (Figure 16). Although these results are highly encouraging, several more years of careful monitoring and evaluation during operational deployment of FWMT will be required before sufficient data accumulate to assess the magnitude of increases to sockeye production attributable to FWMT versus other factors (e.g. increased escapement, improved survival during smolt migration in the Columbia River, improved marine survival).

Finally, the outstanding success of the Okanagan Fish-and-Water-Management Tool over the past four years was recognized when the project and its team members were nominated for a British Columbia Premier's Service Award (Appendix 1). The nomination was put forward by Al Martin, Executive Director of Fish, Wildlife and Ecosystems, British Columbia

Ministry of Environment "as an excellent example of teamwork and vision that allowed all of us to work and learn together to design and build an innovative tool that allows fisheries and water resource managers to better achieve multiple objectives. The annual Premier's awards are the B.C. Public Service's highest awards of recognition and acknowledge achievements in all areas of public service including Cross-Government Collaboration, Innovation, Leadership, Organizational Excellence, Partnership, and Service Excellence. The project and team were honoured with a bronze award for Innovation and Excellence. The award was presented to extremely proud FWMT principles at the Provincial ceremony February 6, 2008. The team included:

- Kim Hyatt, Fisheries & Oceans Canada
- Brian Symonds, Water Stewardship, BC Ministry of Environment
- Clint Alexander, ESSA Technologies
- Andrew Wilson, Fish, Wildlife and Ecosystems, BC Ministry of Environment
- Deana Machin, Okanagan Nation Alliance
- Rick Klinge, Douglas County Public Utility District (Washington State)
- Howie Wright, Okanagan Nation Alliance
- Margot Stockwell, Fisheries & Oceans Canada

Additional accolades were offered by Jim Mattison, Assistant Deputy Director of B.C.'s Water Stewardship Division who noted that; "The tool has really helped, not only improving our operation of the [Okanagan] River, but also greatly improving stakeholder and public understanding of the decisions that we make."

Back row: Howie Wright (ONA), the Honourable Gordon Campbell (B.C. Premier), Clint Alexander (ESSA Technologies), Margot Stockwell (DFO) . Front Row: Dr. Kim Hyatt (DFO), Brian Symonds (B.C. MoE). Missing: Andrew Wilson (B.C. MoE), Deana Machin (ONA), Rick Klinge (DCPUD).

GLOSSARY

Automatic Snow Pillow or ASP: A station where snow water equivalent and other parameters are measured automatically. The data collected are transmitted by satellite (generally every 3 hours). These sites are normally very remote with access by helicopter only.

Cumulative Precipitation: The total precipitation in a region since the previous November 1. Usually expressed as a percentage of normal.

Freshet: The substantial rise in water level of a stream or river caused by melting snow in the spring.

Fish and Water Management Tools Decision Support System: A computerized program for predicting the impacts of various water storage and release options on fish and property.

Hydrograph: A plot of the level or flow of a river over a period of time.

Normal: is the average value of a parameter over a fixed, usually 30-year period. At present the normal period is 1971-2000. Thus the normal water equivalent of a snow-course is the mean value for the 1971-2000 period, for that sampling date.

Regional Snow-pack Index: The sum of the snow-water equivalents at selected representative snow-courses in the region. Often expressed as a percentage of normal.

Scenario: An set of assumptions on the events that take place during a water year (October 1-September 30) in the Okanagan basin. The scenario includes information on water releases through Okanagan Lake dam, RFC inflow estimates and values for various fisheries variables such as peak spawning dates and the threshold total of accumulated thermal units for fry emergence.

Snow-course: A marked location, free from encroachment, where snow depth and snow-water equivalent are measured on a regular basis with standard snow sampling tubes.

Snow-water Equivalent: The water content of a snow-pack at a point, expressed as the depth of water that would result from melting the snow.

Tool: see Fish Water Management Tools Decision Support System

Water Year: The period of time from October of *year n* when sockeye and kokanee spawn, to early November of *year n+1* when salmon fry rearing is complete.

Volume Forecast: A forecast of the volume of water expected to pass a given point on a river (or flow into a lake) in a set time period. This is based on current and antecedent conditions, but assumes normal weather patterns through the forecast period. Units are usually thousands of cubic decameters ($kdam^3$), which is the same as millions of cubic metres.

LIST OF ACRONYMS

ASP	Automated Snow Pillow
ATU	Accumulated Temperature Units
BC-MOE	British Columbia Ministry of Environment
DCPUD	Douglas County Public Utility District
DFO	Fisheries and Oceans Canada
ESSA	ESSA Technologies Ltd.
FWMT	Fish Water Management Tools System
IJC	International Joint Commission
Kdam^3	thousands of cubic decametres = millions of cubic meters
m^3/s	cubic metres per second
MSP	Manual Snow Pillow
ONA	Okanagan Nation Alliance
WSC	Water Survey of Canada
WSD	Water Stewardship Division (BC-MoE)
RFC	River Forecast Centre

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TABLES AND FIGURES

Table 1. Recommended flows for sockeye salmon at various life history stages in the Okanagan River at Oliver (Canada/British Columbia Report on the Okanagan Basin Agreement, 1973).

Sockeye Life History Stage	Dates	Preferred Range (m^3/sec)
Adult migration	Aug. 1 - Sept. 15	8.5 - 12.7
Spawning	Sept. 16 - Oct. 31	9.9 - 15.6
Incubation	Nov. 1 – Feb. 15	5.0 - 28.3 Incubation flows ≥ 50% spawning
Fry migration	Feb. 16 – Apr. 30	5.0 - 28.3

Table 2. Summary of key events or activities (by class and geographic location), risk factors or processes and indicators of relevance for users of the Okanagan Fish-and-Water Management Tools (FWMT) decision support system. The majority of indicators are generated within the FWMT system as model predictions (P) or measured observations (O) that are imported in near, real-time. Stars (❖) represent the primary indicators used for ongoing evaluation of changes in risk. A smaller set of supplemental indicators are generated and accessed by users from outside of the FWMT application (see text for further explanation).

Event or Activity	Risk Factor(s) or Process	Pressure, Status and Trend Indicator(s)	Source			
			Inside FWMT		Outside FWMT	
SOCIO- ECONOMIC						
Okanagan Lake at Kelowna			P	O	P	O
Surface elevation of Okanagan Lake	Okanagan Lake flooding and associated property damage. Okanagan Lake drought and storage deficit that impacts water access for irrigation and domestic water intakes.	❖ Okanagan daily to seasonal snow-pack values relative to average	X	X		
		❖ BC River Forecast Centre or user specified water supply forecast	X	X		
		o Regional snow-pack and/or rainfall events relative to average				X
		o Okanagan daily to monthly rainfall values relative to average	X	X		
		o Hourly to daily inflows from Mission Creek to Okanagan Lake	X	X		
		o Penticton Dam flow releases by hour	X	X		
		o Okanagan River discharge by hour	X	X		
		❖ Net inflows from tributaries relative to weekly or monthly average	X	X		
		❖ Okanagan L. daily to weekly lake level relative to seasonal targets	X	X		
Okanagan River at Penticton						
Discharge and water level in Penticton Channel	Flood induced damage to Penticton channel and/or flooding and water infiltration of riparian properties. Drought induced exposure of domestic and irrigation water intakes.	o Penticton Dam flow releases by hour	X	X		
		o Okanagan River discharge by hour	X	X		
		o Inflows from tributaries relative to weekly or monthly average	X	X		
		o Riparian landowner commentaries re: specific impacts on property				X
		o Flows in Penticton Channel within range for recreational "tubing"	X	X		
		❖ Okanagan R. daily discharge relative to seasonal targets	X	X		
Okanagan River at Oliver						
Discharge and water level in Oliver Channel	Flood induced damage to channel at Oliver and/or flooding and water infiltration of riparian properties. Drought induced exposure of domestic and SOLID irrigation intake at McIntyre Dam.	o Penticton Dam flow releases by hour	X	X		
		o Okanagan River discharge by hour	X	X		
		o Inflows from tributaries relative to weekly or monthly average	X	X		
		o Riparian landowner commentaries re: specific impacts on property				X
		❖ Okanagan R. daily discharge relative to seasonal targets	X	X		

Event or Activity	Risk Factor(s) or Process	Pressure, Status and Trend Indicator(s)	Source			
			Inside FWMT		Outside FWMT	
ECOLOGICAL **Kokanee Salmon in Okanagan Lake at Kelowna**			P	O	P	O
Kokanee spawning and incubation success on Okanagan Lake beaches (SE, NE, NW).	Risk of egg/alevin desiccation and loss due to spawn depth and subsequent lake level draw-down between time of egg deposition and fry emergence.	○ No. of spawners by lake area (SE, NE, NW)				X
		○ Spawn-depth	X			
		○ Lake level	X	X		
		○ Incubation temperature and accumulated thermal units (ATUs)	X	X		
		○ Egg hatch and fry emergence date	X			
		❖ Magnitude of drawdown induced egg/alevin loss during incubation	X			
Sockeye Salmon in the Okanagan River at Oliver						
Adult salmon access to spawning area(s).	Migration blockage at vertical drop-structures due to high discharge. Access to spawning habitat reduced due to low discharge.	○ No. of adult sockeye in riverine spawning grounds	X	X		
		○ No. of adult sockeye in specific spawning areas and habitats	X			X
		❖ Discharge relative to migration & spawning compliance range	X	X		
Egg/alevin incubation and fry emergence success.	Flood or drought impacts on egg/alevin incubation and fry emergence success.	○ Okanagan daily to seasonal snow-pack values relative to average	X	X		
		○ Okanagan daily to monthly rainfall values relative to average	X	X		
		○ Okanagan daily to weekly lake level relative to average	X	X		
		○ Penticton Dam flow releases by hour	X	X		
		○ Okanagan River discharge by hour	X	X		
		○ Unregulated tributary discharge by hour	X	X		
		○ Okanagan R. incubation temperature and ATUs	X	X		
		○ Egg hatch dates	X			X
		❖ Scour and desiccation event-over-threshold drivers	X	X		
		❖ Fry emergence dates	X			X
		❖ Early summer fry recruitment index (no.spawner^{-1}) to Osoyoos L.	X			X

(continued)

Event or Activity	Risk Factor(s) or Process	Pressure, Status and Trend Indicator(s)	Source			
			Inside FWMT		Outside FWMT	
ECOLOGICAL **Sockeye Salmon in Osoyoos Lake**			P	O	P	O
Fry recruitment to Osoyoos Lake.	Flood or drought water-level or flow impacts on fry migration or emergence success.	❖ Discharge of Okanagan River at Oliver relative to emergence and migration compliance range	X	X		
		❖ Early summer fry recruitment index (fry.spawner $^{-1}$) to Osoyoos L.	X			X
Fry rearing in Osoyoos Lake.	Reduction or loss of preferred rearing habitat due to temperature-oxygen "squeeze" (*i.e.* excessive temperatures in surface waters and low oxygen in deeper waters).	○ Calendar day surface temperature in Osoyoos L. exceeds 17°C	X	X		
		○ Seasonal depth of 17°C isotherm in Osoyoos Lake	X			X
		○ Seasonal depth of 4 mg.l-1 oxygen isoline in Osoyoos Lake	X			X
		○ Seasonal depth distribution of sockeye fry	X			X
		○ Average or cumulative discharge July-Sept at Oliver	X	X		
		❖ Volume of "optimal" water (VOW) for fry rearing	X			X
		❖ Early summer-to-fall survival of sockeye fry	X			X

Table 3. Members of the 2007 - 2008 FWMT Operational Team (FWMT-OT).

Agency	Primary Representatives	Alternates
BC Ministry of Environment, Water Stewardship Division	• Des Anderson, Public Safety and Protection	• Ray Jubb • Ken Cunningham • Machelle Tiernan
Fisheries and Oceans Canada	• Kim Hyatt, Research Scientist	• Margot Stockwell
BC Ministry of Environment, Fish and Wildlife Science	• Paul Askey, Fisheries Biologist	• Steve Mathews • Tara White
Okanagan Nation Alliance	• Howie Wright, Biologist	• Kari Long • Ryan Benson
ESSA Technologies Ltd.	• Clint Alexander (technical advisor)	• nil

Table 4. FWMT kokanee and sockeye start-up parameters for water year 2007-2008 (Hyatt el al. 2008).

Parameter		Value
Sockeye Peak Spawn Date		October 15, 2007
Sockeye Escapement (AUC)		13,504
Proportion Females		0.54
	1.1	0.34
Proportion by age:	1.2	0.52
	1.3	0.14
ATU's to 100% Egg Hatch		595
ATU's to 100% Fry Emergence		875
Kokanee Peak Spawn Date		October 18, 2007
Kokanee Escapement		250,726
ATU's to 100% Fry Emergence		950

Table 5: Summary of Record of Management Strategy, Decisions and Outcomes for the 2007-2008 Fish-and-Water Management Cycle. Bullet numbers correspond to events highlighted in Figure 4.

Oct – Dec 2007 (1)	**Event(s) and/or Outlook:** As the result of an extremely dry summer, inflows to Okanagan Lake were sub-average through August-September 2007 (-47 $kdam^3$; all yr mean = -14 $kdam^3$). Consequently, at the initiation of the 2007-08 water year, the lake level was approximately 10cm below the preferred fall-winter benchmarks of 341.9m. Regional precipitation during the fall and early winter was normal; however, inflows to Okanagan Lake remained low throughout this period (75% of average). **Decision:** Reduce discharge for winter incubation period (Figure 4B, #1) but maintain flow at no less than 50% of fall spawning values (i.e. maintain discharge at Oliver of no less than 5.5 cms; Figure 4D, #1) to protect incubating sockeye eggs and to conserve water in Okanagan Lake where levels are below preferred winter benchmarks (Figure 4A, #1-2). **Outcome:** Releases at Penticton Dam were reduced from approximately10 to 5cms (5.6 at Oliver) to (a) protect sockeye eggs and shore spawning kokanee eggs from desiccation and, (b) refill Okanagan Lake to meet winter target levels.
Jan - March 2008 (2)	**Outlook:** The River Forecast Centre predictions for Feb1st and March 1st (Table 6) were based on well below normal snow-pack conditions; overall snow water indices were 81% (Jan), 85% (Feb) and 86% (March) for the Okanagan-Kettle basin. The high elevation pillow at Mission Creek remained below average in January and February (89 and 79%, respectively) but had increased to 90% by March 1st. The low elevation pillow at Brenda Mine was slightly below normal (94%) for January and February but dropped significantly to 84% by March. Inflow estimates to Okanagan Lake were well below normal for February 1st (410 $kdam^3$ or 74% of average) and March 1st (430 $kdam^3$ or 80% of average). This follows on the heels of very low inflows through all of 2007 (Hyatt and Stockwell 2010). The sub-average snow-pack and lake inflow conditions suggest a possibility for below normal stream flow and water supply this summer. **Decision:** Maintain water conservation in Okanagan Lake while providing minimum flow requirements for sockeye incubation in Okanagan River (Figures 4A, 4B & 4D, #2). **Outcome:** Penticton Dam releases were kept at approximately 4cms with flows at Oliver being sustained at approximately 5.7 cms; lake level consistently remained at 341.73 m.
March 25, 2008 Tele-conference	**FWMT Operations Team present:** Kim Hyatt & Margot Stockwell (DFO); Des Anderson & Ray Jubb (Water Stewardship, MoE); Paul Askey (MoE Fish & Wildlife) **Event(s) and/or Outlook:** The current RFC forecast of 430 $kdam^3$ (low-average) was based on snow-pack in the Okanagan region sitting at 89% of normal for the beginning of March. Since this forecast was issued, there has been a substantial increase in snow accumulation and currently the snow pillow at Mission Creek (high elevation ASP) has reached 100% while Brenda Mine (lower elevation ASP) is approximately 94% (Figure 7). Net weekly inflows into Okanagan Lake have been running well below the all year average all winter. This is associated with cold temperatures throughout the winter, i.e. no measurable runoff as everything is still frozen. The short term, regional weather outlook indicates conditions will remain seasonably cooler than average, hence, the potential of increasing snow-packs and the continuation of freezing conditions at higher elevations. Field observations and Belehrádek calculations based on spawning ground

March 28, 2008	temperatures indicate 100% sockeye hatch was complete by the week ending March 8. Additionally, the Belehrádek method is forecasting that sockeye emergence will be complete by May 5-6 or approximately 10 days earlier than the FWMT model is currently predicting. **Issue(s):** Prolonged, cooler conditions increase the potential for sudden, rapid melt later in the season. Current releases from Penticton Dam and Oliver are approximately 7.2 cms. Okanagan Lake is about 20 cm above the April 1 benchmark. Continuation of low release rates combined with above normal lake levels create higher risks of Okanagan Lake flooding and sockeye losses to scour should rapid snow melt occur in April-May (e.g. similar to Spring 2006). **Advice:** (Hyatt) Spills should immediately be increased to begin making room for seasonal runoff. Suggested water release rates (see FWMT Scenario 484; Figure 9) are: immediate increase to 10-12 cms at Penticton with additional increases to 15-25 cms beginning in mid-May. **Decisions:** Water Stewardship (Anderson) agrees to immediate releases of 10 cms as well as to progressively increasing spills described above as necessary. The Ops Team will review release rates again when April RFC forecasts become available (near April 7). Additionally, this moderate release strategy provides ample opportunity for water conservation if the spring runoff turns out to be considerably lower than anticipated. Askey (MoE) is confident that the above strategy poses no risk to Okanagan Lake kokanee (Figure 9A). **Outcomes:** Following the conference call, water management (Anderson, Symonds) compared the current level of Okanagan Lake against the all year average and found this year's level to be slightly above the all year, upper 25th percentile (Figure 10). Given the current projection of near normal run-off, Water Stewardship decided it would be better to increase suggested releases from 10cms to 18cms in order to drop the lake a little more by early April. Flows at Oliver would be monitored closely to ensure they did not exceed 20cms. Penticton Dam water releases were increased to 10cms by March 28, held at this rate for a week (while field crews finished in-stream sampling work), and then increased to ~15 cms by April 8. FWMT identified 100% emergence for Okanagan lakeshore kokanee (March 31st) without any undue loss from premature reductions in Okanagan Lake levels. The "kokanee-friendly" lake level objective was met for this portion of the 2006-2007 fish-and-water management cycle (Figure 4A).
April 6, 2008 (3)	**Issue:** DFO (Hyatt) notes that discharge had not been increased as of this date to the 18cms recommended to begin April 1st by Water Stewardship. Given the continuation of average snow-pack conditions, it would be prudent to act on this recommendation as soon as possible. He is concerned that at this stage, if we don't begin to draft the lake soon, it will create a need for redd-scour inducing rates of spill before sockeye fry are able to complete emergence. The cool weather in March has not only delayed snow melt but also the rate of fry development favouring emergence. Field sampling by the ONA crew as of last week indicates that fry emergence has not yet begun. **Advice:** There is not likely a large time window left to ramp up flows before rising unregulated tributary inputs constrain spill from Okanagan Lake to protect fry. Releases at Penticton Dam should immediately be bumped up from the current 10cms to the recommended 18cms. **Outcome:** Water Stewardship had delayed the increases to support ONA crews who were still completing in-stream work. Releases were made the next day (April 7th) in two increments. Ultimately, Penticton Dam releases were set slightly lower at 15cms (15.4 at Oliver) after the April RFC inflow forecast came in at approximately 82% of

	normal. DFO supported the new releases as FWMT scenarios using this strategy indicate there is still enough manoeuvring room to handle runoff from an average snow-pack, even if it does come down rapidly (Figure 4, #3).
April 14, 2008 (4)	**<u>Issue</u>:** As of April 14th, 2008 high elevation (1780 m) snow pillow data (Mission Creek ASP) stood at slightly above the all year average (Figure 7). By contrast, low elevation (1460 m) snow pillow data (Brenda Mine ASP) indicated a level of roughly 6% below the all-year average. Taken together, snow pillow observations place us in a very similar "supply situation" to that observed during the spring of 2007 when the subsequent limited yield of water inflow from melting snow-packs required initiation of water conservation relatively early in the season (Hyatt and Stockwell 2010). Consequently, early actions for water conservation may be required again in the spring of 2008. **<u>Event(s) and/or Outlook</u>:** Unseasonably cool temperatures (mean air temperature for March was the lowest on record) have impeded early initiation of snow pillow melt or any major increases in net flows from tributaries into Okanagan Lake. The RFC forecast projects below average inflows to Okanagan Lake April 1st to July 31st (390 ± 90 kdam³). Weekly net inflows have remained well below average since early January and have been running at less than 50% of the all-year average from mid-March to April 8th. Significant increases in air temperature over the weekend of April 13th -14th was accompanied by noticeable increases in flows at the Mission Creek, Inkaneep and Vaseux Creek WSC gauges. However, flows at all three gauges are still lower than at this date in 2007. Okanagan Lake levels at Kelowna have decreased by about 2 cm since April 7th in association with water releases that were increased from 10 cms to 15 cms on April 8th (Figure 4A and B; #4). For comparison, Okanagan Lake level is currently 1.5 cm lower (on a decreasing trend) than it was on April 14th of 2007 (when lake level exhibited an increasing trend). The Environment Canada 5-day forecast is for continued cool weather so significant increases in tributary inputs are not expected this week. Weekly sampling for sockeye fry emergence is underway. Sampling on April 2nd and again on April 9th suggests fry emergence has barely begun (i.e. an hour of trapping produced only 3-5 fry on each date). Cool spring temperatures may be expected to delay the peak of fry emergence into late April or early May (Figure 11). **<u>Advice</u>:** Given a near average snow-pack and sub-average water yield by way of inflow to tributaries, there appears to be little imminent risk of a flood event in 2008 barring above average spring precipitation. Moreover, it may be prudent in the short run to decrease spill from 15 cms to 12 cms at the Penticton Dam to stabilize Okanagan Lake at its current level until we have a better idea of the expected water yield of the current snow-pack to Okanagan Lake. If water yield were to follow last year's pattern, then additional steps to conserve water for summer and fall use could materialize as early as the middle of May. FWMT Scenario (Figure 12) indicates that it should be feasible to maintain "fish friendly" flows throughout the season without incurring any undue risk of flood. **<u>Decisions</u>:** Pending further information on weather and hydrologic conditions in late April and early May. **<u>Outcome</u>:** Water releases were reduced as recommended above (Figure 4B, C, and D, #4).
May 1, 2008 **Tele-conference** (5)	**<u>FWMT Operations Team present</u>:** Kim Hyatt & Margot Stockwell (DFO); Des Anderson, Ken Cunningham & Machelle Tiernan (Water Stewardship, MoE); Ryan Benson (ONA) **<u>Event(s) and/or Outlook</u>:** May RFC forecasts are not yet available but are expected to be slightly above April's estimate of 390 kdam³. The Okanagan Basin received significant late winter snowfall and is currently experiencing a colder than normal

	spring. The current overall Okanagan snow-water index is 103%, an increase from the April 1st estimate of 93%. Continuing cool temperatures are contributing to an extended delay in spring melt. Mission Creek (high elevation ASP) is slightly above the all year average (102%) and to date is still increasing. Brenda Mine (low elevation ASP) is well above average (122%) but air temperatures at this site have been above freezing for at least a week. As a result, unregulated tributary flows (Vaseux, Inkaneep) are just starting to show minor increases in discharge. However, tributary flows continue to have a negligible effect on discharge rates near Oliver. Net inflows into Okanagan Lake remain far below seasonal norms (19 mil m^3 in April 2008 versus all year April average of 88 mil m^3). As advised during April 15 teleconference, Penticton releases were cut back to 10cms (from 15) to stabilize Okanagan Lake at its current level (~341.7). Weekly field sampling for sockeye fry in the Okanagan River confirms that emergence peaked around April 22 (Figure 11). Field observations, FWMT predictions, and independent Belehrádek calculations based on spawning ground water temperatures, all indicate sockeye emergence will reach 100% by May 5 to 8. **Issue(s):** The prolonged, cooler than normal conditions of this year suggest a delayed spring melt. The extended delay along with higher snow accumulations could potentially create some flood risk by way of a compressed, high volume freshet. However, at present, lake levels are low enough to accommodate additional inflow. Furthermore, sockeye fry may be considered safe from scour by the end of the first week in May should higher inflows necessitate ramping up water releases at Penticton Dam. **Advice:** Release strategies can move away from fisheries issues (avoidance of desiccation/scour situations) and focus on flood prevention in the near term and water conservation for summer in the longer term. Current conditions suggest that water managers have "room to manoeuvre" as the present lake level will be able to accommodate increased inflows from a late run-off. FWMT indicates Okanagan Lake may not reach peak pool (June 24 benchmark) but will attain the preferred level(s) at the remaining summer benchmarks. **Decisions:** Increase water releases to 15 cms, ramping up as increases in water yield warrant. Revisit this strategy in approximately four weeks when RFC forecast and late spring weather conditions are known. **Outcome:** Within a few days of the teleconference call, discharge from unregulated tributaries began to increase as a result of considerable melt from low elevation snow-packs. Releases from Penticton were held at 10 cms as discharge at Oliver was increasing daily due to additional tributary contributions (Figure 4B & D, #5). FWMT identified 100% emergence as May 7th; field sampling confirmed approximately 96% emergence by this date. Sockeye friendly water release objectives were met for the 2007-2008 fish-and-water-management cycle (Figure 4D).
May 14, 2008 (6)	**Event:** There were significant accumulations of snow at higher elevations during the first two weeks of May such that the snow-water index at Mission Creek ASP is now approximately 150% of the all year average. Environment Canada is predicting extremely high temperatures in the Southern Interior over the next several days (e.g. highs of 30+ °C at Kelowna) which will undoubtedly initiate rapid melt and high volume run-off. **Advice:** DFO (Stockwell) advises Water Stewardship that sockeye fry emergence could be considered complete as of May 6th (96% emergence). With the fry safely emerged, WSD is free to ramp up discharges as much as necessary in order to accommodate anticipated elevated inflows. **Outcomes:** Releases at Penticton decreased to approximately 5.6cms in response to escalating unregulated tributary inflows downstream of Okanagan Lake (Figure 4B &

	D).
May 29, 2008	**Event(s) and/or Outlook:** (1) Unregulated tributary inflows have peaked and are declining (so ignore the model projections suggesting unregulated tributaries will spill more water - unless its driven by future rainfall (Figure 19C), (2) the low elevation snow-pack is long gone, (3) the high elevation snow-pack (Mission Creek ASP) is about 30% gone and, although it should be possible to hit full-pool storage in Okanagan Lake, weekly melt and precipitation will have to be followed closely as we could shift rapidly from more than adequate water supplies to a need for less spill/ more storage dependent on June precipitation levels. At this stage, and given a cooler than average spring, we are not anticipating a severe temp-O_2 squeeze in Aug-Sept (i.e., FWMT suggests water supplies are sufficient to meet spill levels required to suppress any severe squeeze effect; Figure 21D). Although this suggests a relatively benign water year for threats to fish, we will continue to "track" fish-and-water interactions and comment as warranted as the summer progresses.
June 1, 2008 (7)	**Event:** Releases from Penticton Dam were bumped up to approximately 23 cms for 4 days to help the ONA facilitate the release of hatchery reared sockeye fry in Penticton Channel near Shuttleworth Creek. The fry are from the Skaha Reintroduction Program. Higher flows prevent the fry from becoming entrained in gravel areas along the sides of the channel.
June 10, 2008 (8)	**Event(s) and/or Outlook:** Five days of well above normal temperatures over May 16-20 triggered rapid snowmelt resulting in: (a) above average inflows to Okanagan Lake for 2 weeks, and (b) rapid increase in discharge contribution to the Okanagan River from unregulated tributaries. Normal to above normal temperatures for the remainder of May maintained the progress of snowmelt. Additionally, the first week in June received considerable precipitation with current forecasts calling for continuing heavy rain (e.g.10mm for June10) near Kelowna. **Issue:** High inputs from rapid snowmelt and recent heavy rainfall at Kelowna has significantly advanced the projected time for Okanagan Lake to reach full pool. Okanagan Lake is currently less than 8 cm below the June 24th maximum target of 342.54m with the level rising at approximately 2cm/day. **Decision:** WSD will initiate aggressive releases at Penticton Dam as full pool approaches. Release from Okanagan lake was increased from approximately 5 to 20cms June 9, with a plan to increase again to 30cms this morning. This rate has now been revised upward, with a plan to increase discharge to 35cms in the morning and hopefully, to 50cms later today (Figure 14). **Advice:** Hyatt and Alexander both suggest that increasing discharges to 35-40cms should be sufficient to manage expected inflows and to keep Okanagan Lake from surpassing full pool. This assumes that "true" net inflows lie between the average and low May 1st RFC forecast. Additionally, the forecast date of full pool is likely somewhat exaggerated (by 3-4 days) in FWMT, as shown by the departure in the trend between the real-time data and the forecast lake elevation (Figure 15). This owes to the all year nature of the weekly disaggregation used in the model for forecasting. Sustained heavy rains lasting 2-3 days are therefore, most likely needed before releases of 50+cms should be warranted. They recommended the lower flows but also applying a close watch to lake level elevation and inflows. **Outcome:** Water releases at Penticton Dam were increased to 50cms by June 11 and then dropped back down to an average of 37cms for the remainder of the week (Figure 4B, #8).

June 19, 2008

(9)

<u>Event(s) and/or Outlook</u>: WSD Water Release Plans for June and July

<u>E-mail to FWMT Operational Team From Des Anderson</u>

Discharge at Penticton Dam is currently about 21cms, with plans to hold at this rate for the current time step (ending June 24th). Releases were decreased recently to counter dropping tributary inflow contributions and increasing evaporation losses. Okanagan Lake currently sits approximately 4.3 cm below full pool. Rate of lake level rise is forecast at near 0 cm/day for the next week. Since the full pool target date is June 24, it seems likely the lake will be approximately 3.0 to 5.0 cm below full pool by June 24th. Since the lake level target level by June 30 (according to the OLRS Operating Plan) is 342.44 m (new datum), the lake should be close to this level by this date. Mission Creek is still responding somewhat to melting of the remnants of the snow-pack, but snowmelt is not generating significant runoff due to diminishing contribution area. Temperatures are forecast to be in mid-20's to upper 20's in valley bottom, with probability of precipitation low (Kelowna) for the next week. Skaha and Vaseux lakes are quite steady, so any adjustments should not be required until early next week.

<u>Decisions</u>: As shown in Scenario 497 (Figure 14), releases will be ramped up somewhat during late June and July in order to meet the July month-end target lake level of 342.24 m (new datum). However, the plan is to store water in Okanagan Lake for a late summer pulse to Osoyoos Lake to help mitigate a temperature-oxygen squeeze. This is reflected in the current release schedule below for the next weekly time steps in FWMT. An FWMT conference call is to occur during July to discuss lake storage options, releases and timing for the oxygen squeeze.

Time step end date	cms
25: 24-Jun	21
26: 01-Jul	35
27: 08-Jul	40
28: 15-Jul	40
29: 22-Jul	35
30: 29-Jul	30

(10)

<u>Outcome</u>: Penticton Dam releases were cut back to approximately 15cms on July 8 in response to a major decrease in inflows to Okanagan Lake (Figure 8B).

July 11, 2008

<u>Event(s) and/or Outlook</u>: Okanagan Sockeye Return Strength and Questions about flow.

<u>E-mail to FWMT Operational Team From Kim Hyatt</u>

A few of us have experienced a higher than average number of queries regarding Okanagan sockeye return strength and associated information and issues this year (Figure 16). Explanations for 2008 returns exceeding both the historic average and the pre-season forecast should reflect a balanced treatment of what we know as follows: (1) the returns predicted (75,000 at Bonneville) this year were forecast to be above the all-year average given higher than average smolt outputs from the Okanagan in particular, (2) both the sockeye re-introduction project at Skaha and the Fish-and-Water Management Tools project to ensure fish friendly flows have contributed to increased smolt output in recent years, (3) smolts originating from the Skaha project comprised about 10 % of the total Okanagan smolt production in spring 2006 so although they are making a contribution to 2008 returns, the majority of Okanagan fish returning in 2008 will be from wild production which also benefited from the FWMT project, (4) given our estimates of smolt numbers leaving in 2006, its apparent that mainstem-and-marine survival rates were far above the all-year average so good flows and improvements in fish passage along with better conditions during early marine life all provided a boost to survival (i.e., its not just about the

	Canadian project effects although we should certainly take some credit) and (5) post season analysis will eventually allow us to reliably specify the overall stock composition of the 2008 Columbia sockeye return as to proportions originating from: Osoyoos Lake, Skaha Lake, Wenatchee Lake, and Redfish Lake. DFO personnel have been receiving questions about appropriate flows to maintain in the Okanagan River. Water Stewardship has recently dropped releases at the Penticton Dam to reflect the need to conserve water for later in the season to mitigate for a potential temp-oxygen squeeze that will set up in Osoyoos Lake unless we're able to maintain flows above 10 cms through Aug-Sept. Given the number of adult sockeye downstream in the Columbia at Wells and in the Okanagan River below the Similkameen, there will be queries about whether we should be releasing more water at the Penticton Dam under the assumption that this will influence either flow or temperature conditions that might affect sockeye passage. Some short comments about this are as follows: (1) none of our analysis suggests seasonal flows have had much influence on passage in the Okanagan below its junction with the Similkameen so as long as conditions are within the recent historic range there's no reason to adjust flows to ease passage in the U.S., (2) although inputs from the Similkameen influence seasonal temperatures in the lower Okanagan (i.e. snow-melt cools the lower river) releases from Canada do not because out flowing water consists of "surface skim" from Osoyoos Lake so variable releases of water from the Penticton and/or Osoyoos Dams will not cool lower river temps that are known to delay entry of adult sockeye into the Okanagan River. Accordingly, flow management in Canada should continue to focus on conservation and mitigation of local conditions such as flows on the spawning grounds or temperature-O_2 squeeze mitigation in Osoyoos Lake. Finally, if water managers are uncomfortable fielding questions about Okanagan sockeye and flow relations I'll agree to serve as a point of contact for such queries. **Issue:** Water management would like to initiate annual release reductions (to approximately 10 cms) in order to conserve water in Okanagan Lake for the summer. However, they are concerned that the low flows would have a detrimental effect on the unprecedented, large numbers of adult sockeye that are present in the river below McIntyre Dam. **Advice:** Penticton Dam releases should be cut to 10 cms as requested. This discharge rate is well within the range (8.5 - 12.7 cms) recommended for adult sockeye migration. Water temperatures in the Okanagan River are currently very high (21°C) and increasing. Sockeye will commonly halt their migration at temperatures >21°C. As temperatures increase, they will likely drop back and hold in the cooler waters of Osoyoos Lake, recommencing migration when river water begins to drop below 21°C. **Outcome:** Water releases from Penticton Dam are reduced to conserve water in Okanagan Lake for summer storage. Flows will be increased as required to meet domestic and agricultural water requirements (Figure 4B, C, & D, #10).
July 27, 2008	**Issue:** Potential for significant reductions in sockeye rearing habitat in Osoyoos lake due to development of a temperature-oxygen "squeeze" in September, 2008. **Event(s) and/or Outlook:** A near average snow-pack combined with an exceptionally cool spring and prolonged period of snowmelt permitted a well controlled pattern of Okanagan Lake water release and storage such that by late June lake levels were near the preferred, full-pool benchmark (Figure 4A, #10). However, total precipitation through the late winter and spring was well below the all-year average. A general pattern of sub-average precipitation has persisted through June (75 % of normal) and July (25 % of normal). Net water inputs from tributaries into Okanagan Lake assumed negative values (i.e. evaporative losses greater than inputs) by the week beginning

	July 15th some 3 weeks earlier than average (see net weekly input Figure 8B). Consequently, water releases at the Penticton Dam have been reduced from around 28 cms in early July to about 12 cms as of July 27th (Figure 4B, #10) to conserve water to meet irrigation, fisheries and domestic requirements into the late summer and fall. If drier than normal summer conditions persist through Aug-Sept, then the "graphs low" version of FWMT Scenario-506 (Figure 22A) appears most likely and suggests the possibility that a late summer-fall temperature-oxygen squeeze may be induced in Osoyoos Lake. Graphs-low Scenario-506 displays an amber warning condition as of mid-July and anticipates a red-hazard condition materializing by late September of 2008. By contrast, graphs-average Scenario-506 (Figure 22B) suggests that average rainfall and associated water releases through August and Sept. will avoid development of a severe habitat-limiting "squeeze" condition for juvenile sockeye rearing in Osoyoos Lake. **<u>Advice</u>:** Water releases should be maintained to achieve a daily average of no less than 10 cms for the interval from August 1st through Sept. 30th to avoid inducing a temperature-oxygen squeeze in Osoyoos Lake. If possible, a pulsed water release of approximately 25-35 cms should be planned for the Aug.15th to Sept. 7th interval to test the utility of elevated flows for "flushing" excess organic matter from the epilimnion of Osoyoos Lake. An early August conference call should be scheduled to discuss actions that may be taken given the advice herein. **<u>Decisions/Outcome</u>:** Pending outcome of discussions from August conference call.
August 15, 2008 (11)	**<u>Issue</u>:** Persistent potential for significant reductions in sockeye rearing habitat in Osoyoos Lake due to development of a temperature-oxygen "squeeze" expected in September, 2008. **<u>Event(s) and/or Outlook</u>:** A persistent pattern of sub-average precipitation through June (75 % of normal) and July (25 % of normal) into early August recommended careful water conservation resulting in sub-average flows through Osoyoos Lake through much of the summer. Early recognition of the need for conservation plus additional water yield from recent late summer precipitation events appear to have created some scope to entertain a late summer "pulsed release" of water at Penticton Dam to mitigate against an early onset of undesirable temperature-oxygen "squeeze" conditions that reduce juvenile sockeye rearing and adult pre-spawn, holding habitat in Osoyoos Lake. Vertical profile observations of temp-O_2 in Osoyoos Lake on July 21st, 28th and Aug. 11th indicate water less than 17°C remains at depths below 11m and that the threshold of water of less than 4 mg per litre of O2 has not been exceeded at any depth to date (i.e. O_2 concentrations in bottom waters at > 30 m depths are at 7.8 mg/litre). However, comparisons of oxygen concentrations at depth between July 21st and August 11th indicate a progressive consumption of oxygen in the Osoyoos Lake hypolimnion is underway (i.e. O_2 values in hypolimnetic waters are less than 7 mg/litre by comparison with greater than 9 mg/litre at the lake surface). Multiple FWMT Scenarios (e.g. Figure 22) suggest that persistent maintenance of flows averaging less than 15-20 cms through late August and September will induce a temperature-oxygen squeeze. By contrast release of a pulsed flow of water of 30-35 cms to "flush" epilimnial waters of Osoyoos Lake for a 3 week interval between August 22nd and Sept 15th will impede development of severe squeeze conditions (Figure 22). FWMT projections suggest flow releases of this magnitude and duration may be implemented without undue risk of drafting Okanagan Lake below preferred fall benchmarks for beach spawning by kokanee in Okanagan Lake. **<u>Advice</u>:** Teleconference discussions of the multiparty FWMT Operations Team on

August 22nd – Sept 11th	August 6th and then again between K. Hyatt (DFO) and D. Andersen (BC-MOE Water Stewardship Division) on August 12th suggest that current water supplies are sufficient to support a late summer pulsed flow release. Hyatt-Andersen agreed that it appeared feasible to plan for a pulsed water release of approximately 30 cms on August 23rd extending to Sept. 11th to test the utility of elevated flows for (a) "flushing" excess organic matter from the epilimnion of Osoyoos Lake and (b) eliminating or reducing the onset, duration and magnitude of a temperature-oxygen "squeeze" in the deeper waters of Osoyoos Lake in 2008. Note, WSD (Andersen) requested an Aug 23rd start date to accommodate efforts to remove two beaver lodges and associated debris from mainstem channel areas in the "safe work window for fisheries" and prior to flow release elevations. A late August start to a pulsed flow may also be more advantageous in removing senescent algal biomass from the epilimnion of Osoyoos Lake. **Decisions:** Plan for a pulse release of water is supported and will be initiated given confirmation of an adequate water supply just prior to August 23rd, 2008 as the start date for a pulsed release of water. **Outcome:** Anderson confirmed in an Aug. 22nd e-mail that water releases at the Penticton Dam would be elevated from 11 to at least 30 cms would be initiated in a stepwise fashion beginning late on the afternoon of Sept. 22nd. Observations of water quality conditions and juvenile or adult sockeye responses to changes in lake and river conditions will be assessed as the pulsed flow release progresses. **Revised Outcome at 8-Sep-08:** Water releases at the Penticton Dam were elevated from 11 to 30 cms in a stepwise fashion beginning late on the afternoon of Aug. 22nd. Temperature and oxygen profiles from Osoyoos Lake as of Sept. 7th indicate temperature and oxygen levels from 14m to the lake bottom are close to their all-year average values and remain satisfactory for occupation by juvenile sockeye salmon. Although some risk of a late season temp-O2 squeeze may remain until October, risk of an early onset, prolonged squeeze condition (i.e. late Aug. to early Oct.) has passed.
Sept. 19, 2008	**Technical Issue**: Multiple runs of current FWMT scenarios by separate "owners" (Stockwell, Hyatt, Anderson) at or near 17-Sep-08 resulted in 3 slightly different versions of the Osoyoos Lake chart in the Main Assessment reports. FWMT operators were concerned that the differences may be due to the model performing incorrectly. **Event(s) and/or Outlook**: Outputs from multiple FWMT updates run on 17-Sept provided conflicting/different results as indicated by the Osoyoos T/O_2 squeeze hazard bars which represent remaining habitable rearing volume as well as the trajectories of the 4ppm O_2 isopleth depth. Examination of the data input sheets also showed variation in the weekly (5-Aug through 21-Oct) useable water volume values (UWV) and the O_2 isopleth depth values. These results were puzzling as we had assumed that all values to Sept. 17 were observed rather than predicted and that all simulations would show identical outcomes prior to Sept. 17th. **Advice**: (from C. Alexander) Sept. 16th represents the date of minimum habitable water volume in Osoyoos Lake and is a "special date" within the T-O_2 squeeze algorithm. The daily position of the 4 ppm O_2 isopleth between Aug. 1st and Sept. 16th and then from Sept. 16th to Nov. 1st, is determined by linear interpolations between the specific values provided on July 31st, Sept. 16th and October 31st. The differences between scenarios may be due to minor interpolation/rounding errors centered around the 16th. Wait a day or two and then complete additional runs to see if the problem still persists. **Decisions and Conclusions**: Discrepancies between outputs are due to variations in user defined outflow forecasts and subsequent differences in estimates of mean daily discharge for the month of September.

	Outcome/Rationale: The date on which useable water volume in Osoyoos Lake reaches its minimum has been assigned to Sept. 16th (an all year mean date). UWV values at this date are determined by the mean daily discharge at Oliver for the complete month of August or September (whichever is larger; 2008 = Sept). Thus, the mean daily discharge for either month will be based on combinations of observed and predicted daily discharge for any day prior to the end of either of these months. The estimated depth of the 4 ppm O_2 isopleth on the 16th is specified in two steps which include (1) application of a mean discharge to the UWV regression to predict UWV and then (2) identification of the depth that the 4 ppm O_2 isopleth must assume to satisfy both the UWV value and the all year mean depth of the 17°C temperature isopleth. Hazard bar colours are related to the depth of the O_2 isopleth on any given day. The value of UWV and the behaviour of the 4 ppm O_2 isopleth are dynamic and are recalculated/re-interpolated on a daily basis (July 31st to Sept.16th to October 31st) as the model is updated with real-time feeds and as forecast releases change. Thus, variations in user defined outflows will provide different estimates of UWV and O_2 depth and consequently, hazard displays and O2 isopleth trajectories. **For a detailed description of FWMT interpretative depiction of the Osoyoos Lake temperature-oxygen "squeeze", see pp 118-123 Record of Design (located under the Help tab of the model;** Alexander et al. 2008).
Sept. 29, 2008	**Year-end Outcome:** Surface temperatures in Osoyoos Lake have dropped below 17°C so the risk of any severe temperature-oxygen squeeze impact on sockeye rearing-and-holding habitat has passed (Figure 4E). Thanks to the operations team for the exceptional level of cooperation achieved to make the 2007-08 fish-and-water management year a great success. In particular execution of a late season pulsed-discharge through Osoyoos Lake has been accompanied by increased hypolimnetic O_2 levels through Sept. (Figure 17). Final estimates of 2007 Brood Year sockeye smolt production will not be available until after late winter (Feb-Mar/09) acoustic and trawl surveys are completed. However, FWMT outputs to the end of Sept. may be safely assumed to represent year-end results illustrating the record of management strategy (ROMS), decisions and outcomes for fish-and-water year 2007-08. Various year-end records from FWMT are attached below in support of assembly of the 2007-08 ROMS document.

Table 6. Inflow estimates (Kdam³) to Okanagan Lake entered into the Fish-Water-Management-Tool System for water year 2007-2008. Estimates are provided by personnel from the BC River Forecast Centre at the beginning of each month (Feb to May). The historical average is based on 33 years (1974 - 2007) of data.

Forecast Period (2008)	Uncertainty Type	RFC Estimate (Kdam³)	Historical Average (Kdam³)	Actual Total for 2008
Feb 1 - Jul 31	Mean -1StDev	328	294	
Feb 1 - Jul 31	**Mean**	**410**	**517**	**399**
Feb 1 - Jul 31	Mean +1StDev	492	740	
Mar 1 - Jul 31	Mean -1StDev	340	284	
Mar 1 - Jul 31	**Mean**	**430**	**500**	**390**
Mar 1 - Jul 31	Mean +1StDev	520	716	
Apr 1 - Jul 31	Mean -1StDev	300	265	
Apr 1 - Jul 31	**Mean**	**390**	**470**	**377**
Apr 1 - Jul 31	Mean +1StDev	480	675	
May 1 - Jul 31	Mean -1StDev	289	199	
May 1 - Jul 31	**Mean**	**370**	**382**	**358**
May 1 - Jul 31	Mean +1StDev	451	565	

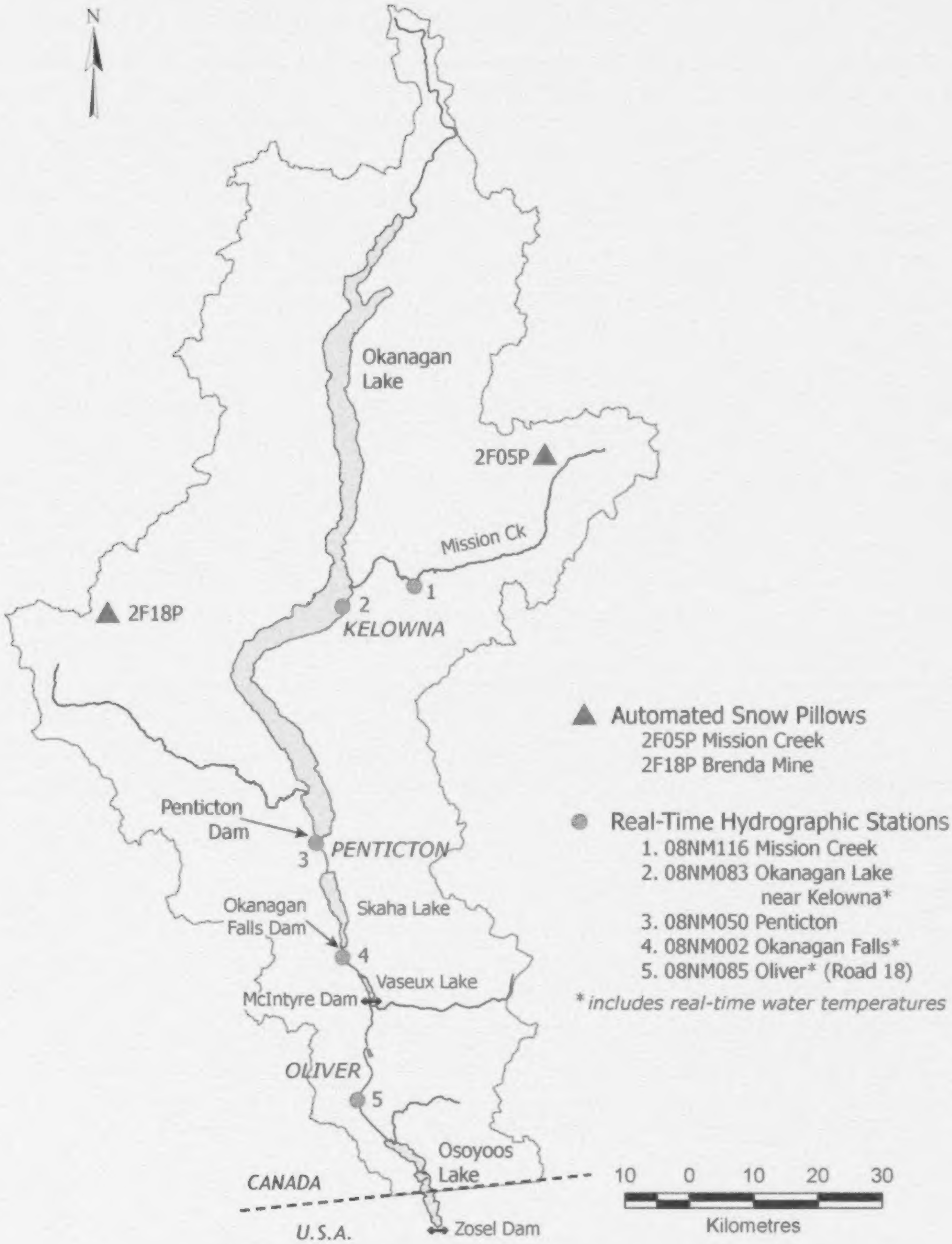


Figure 1. Map of major lakes, dam sites (Penticton, Okanagan Falls, McIntyre, Zosel), monitoring stations (snow-pack, water supply, and temperature) and towns within British Columbia's Okanagan Basin.

FWMT Decision Support System

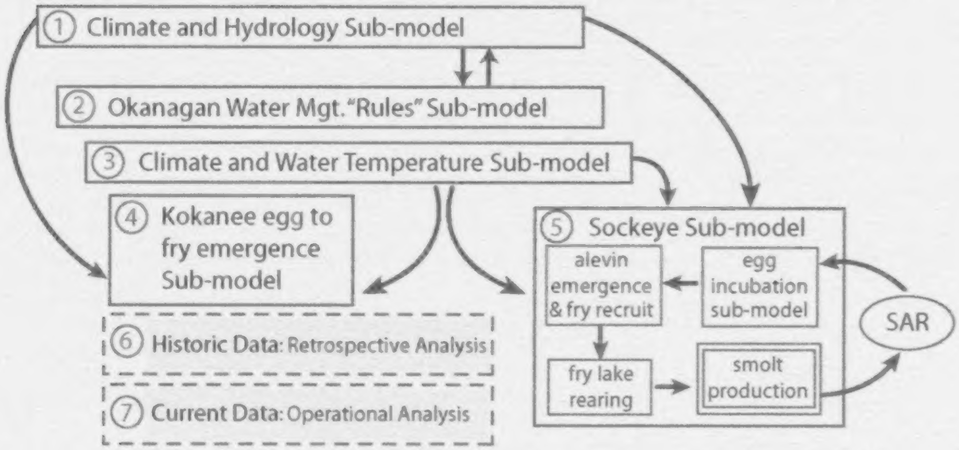


Figure 2. FWMT is a coupled-set of 4 biophysical models of key relationships among climate, fish and water that interact with a fifth, water-management rules model used to predict consequences of water management decisions for fish and other water users. FWMT software allows system users to explore water management decision impacts in near "real-time" (current-mode), historic intervals (retrospective-mode) or future intervals (prospective-mode) given data on water supplies, climate and fish population state(s).

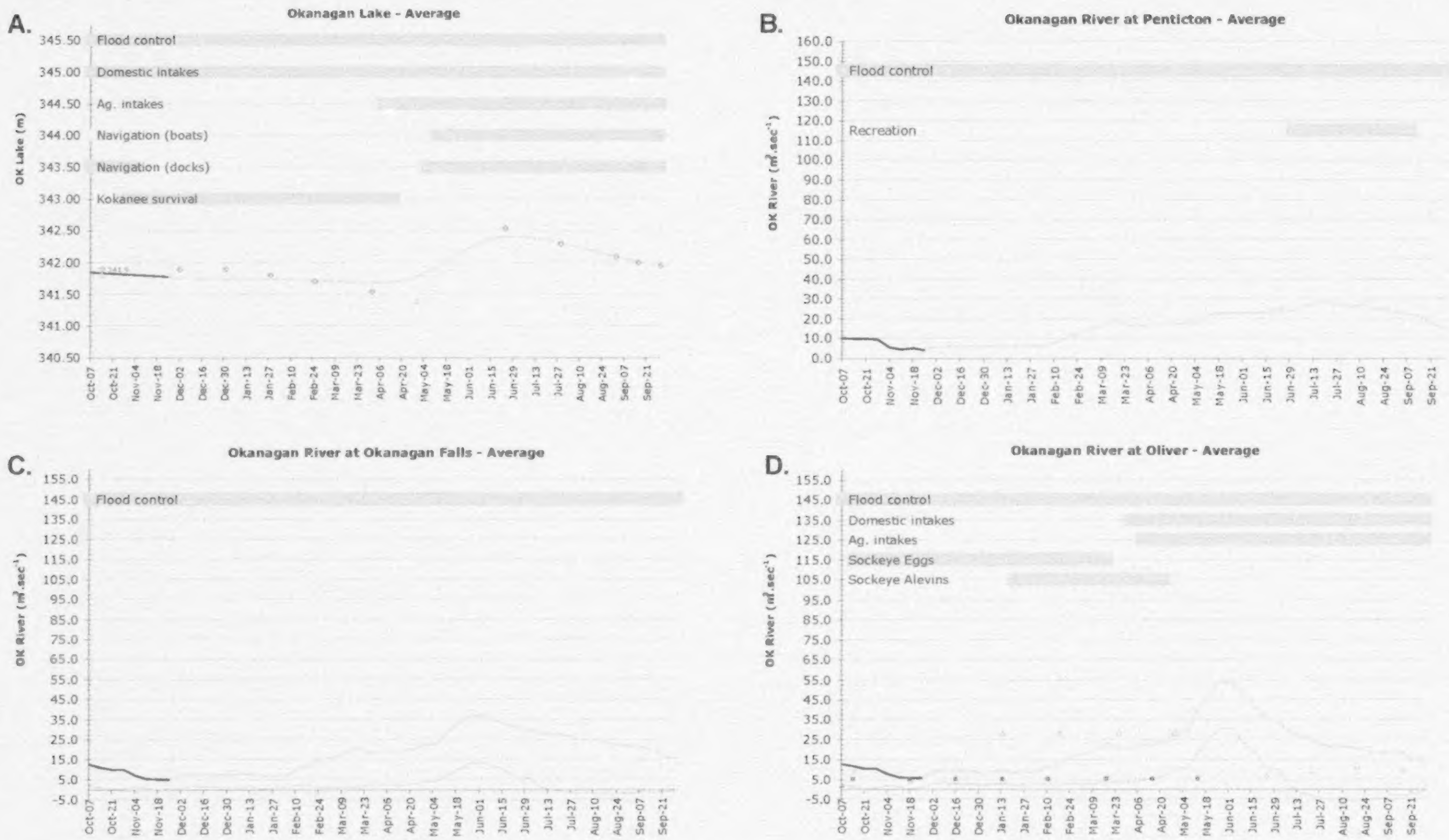
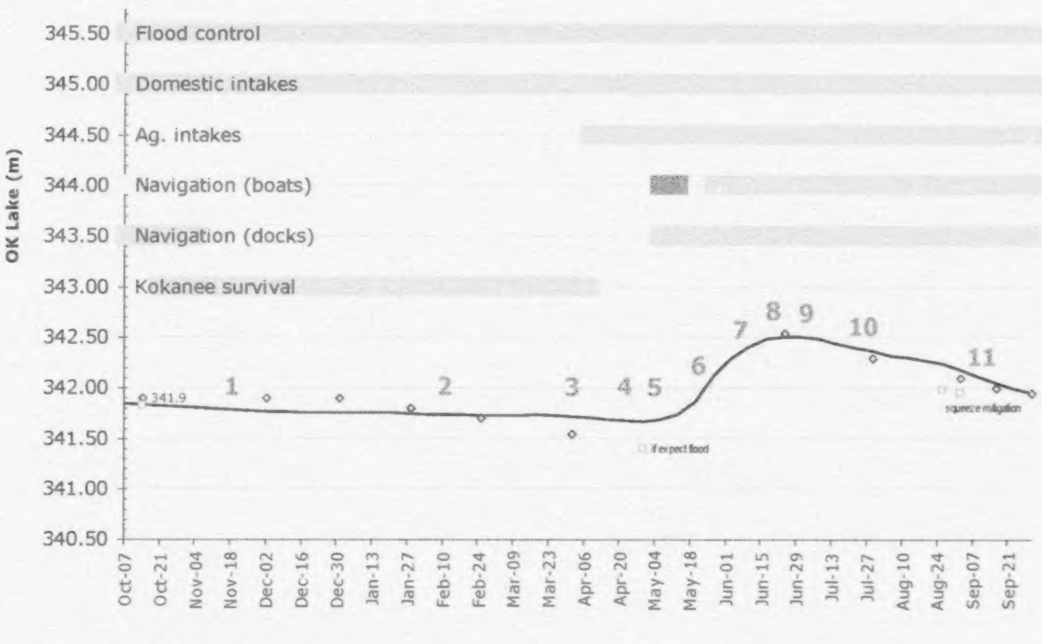


Figure 3. Results of FWMT Scenario 389 run by Margot Stockwell on December 6, 2007. Solid black lines represent observed lake level elevations or river discharge to date. Blue lines are predicted lake elevations and flows by location, given (a) an RFC or user specified annual inflow forecast and (b) a user specified pattern of water storage or release at the Penticton Dam. Green diamonds (Panel A) are preferred seasonal targets for Okanagan Lake level management. Yellow triangle (Panel A) identifies preferred lower target for Okanagan Lake in late winter in advance of peak, spring-freshet inflows given an above-average snow-pack. Red lines (Panels C and D) are either observed or predicted seasonal inflows from unregulated tributary streams. Red triangles and black rectangles (Panel D) mark the sockeye egg/alevin scour and desiccation thresholds.

(A) Okanagan Lake at Kelowna



(B) Okanagan River at Penticton

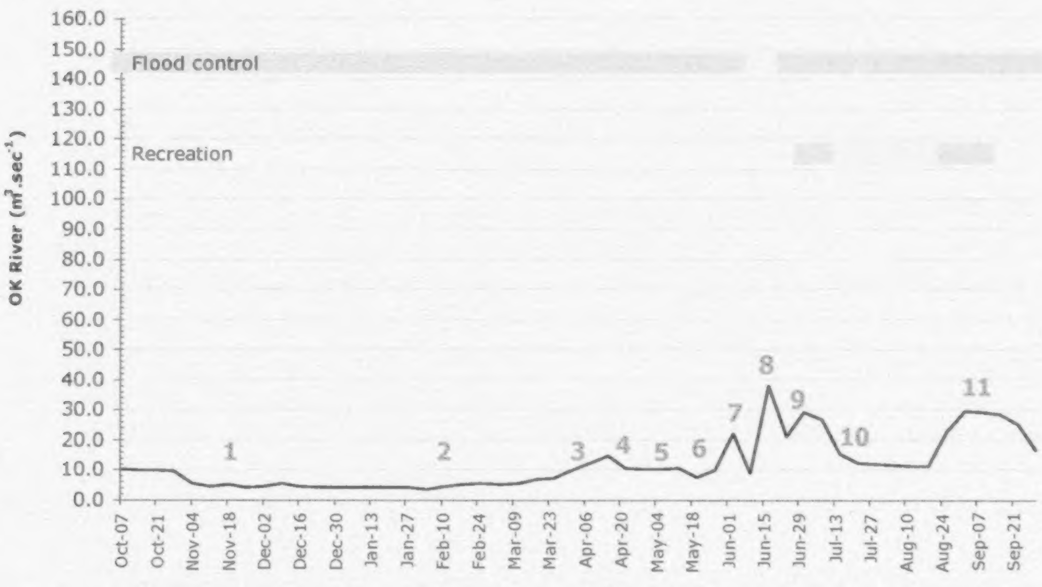
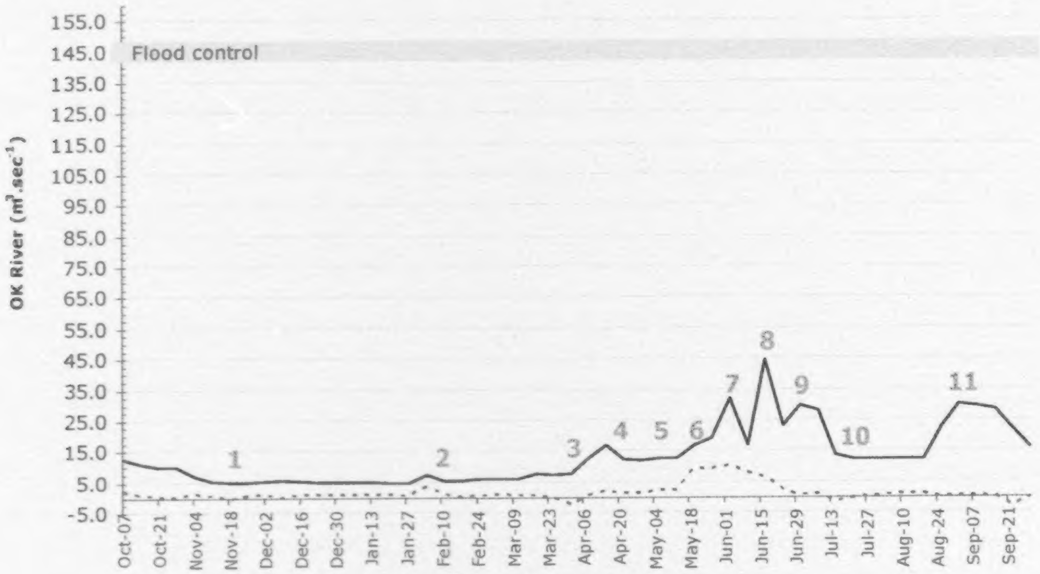
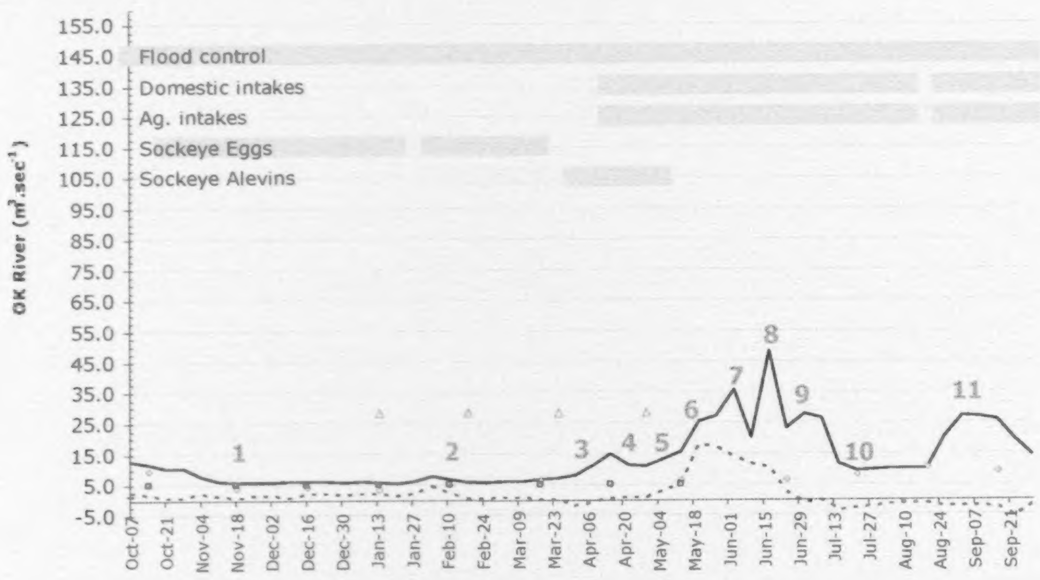


Figure 4. Final FWMT outcomes for water year 2007-2008 for (A) Okanagan Lake level at Kelowna and Okanagan River discharges at (B) Penticton, (C) Okanagan Falls, (D) Oliver, (E) Osoyoos Lake juvenile sockeye rearing conditions in Osoyoos Lake. See Table 5 for commentary corresponding to bullet numbers.

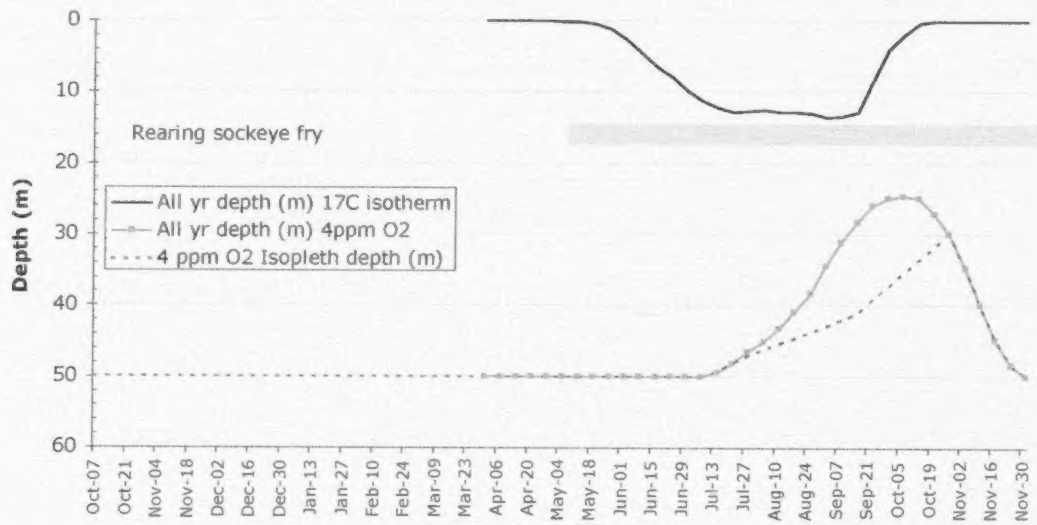
(C) Okanagan River at Okanagan Falls



(D) Okanagan River at Oliver



(E) Osoyoos Lake Temperature-Oxygen Squeeze Indicator



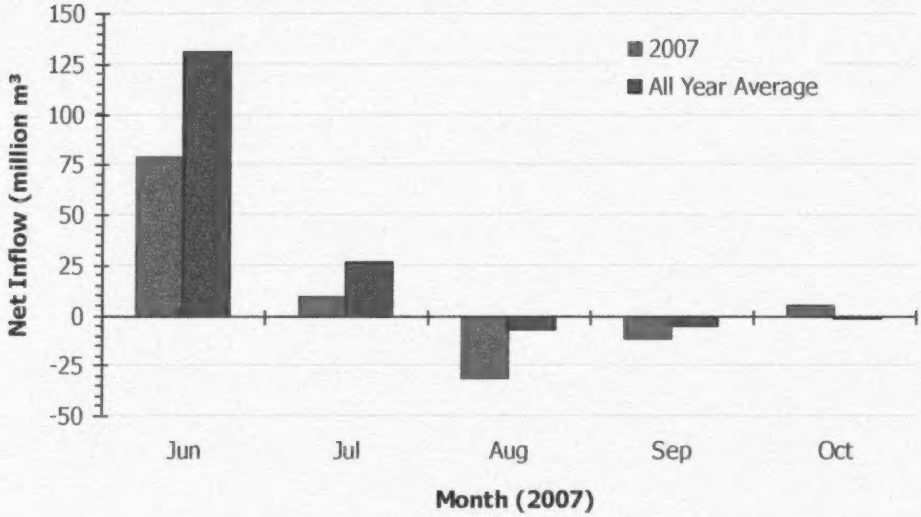


Figure 5. Net monthly inflows to Okanagan Lake during the summer of 2007 compared to the all year average (1974-2007). Negative inflows result from water withdrawals for irrigation and evaporative losses from Okanagan Lake.

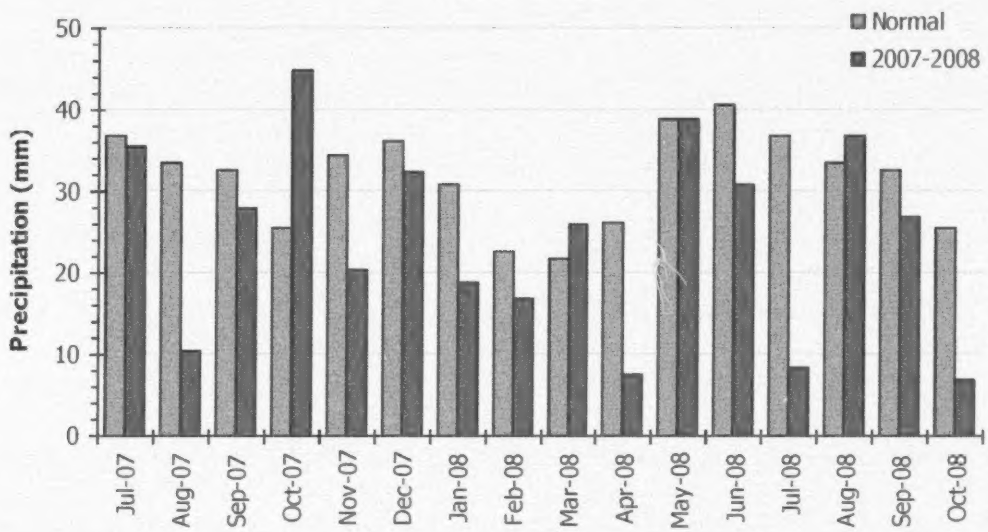


Figure 6. Total monthly precipitation (mm) at Environment Canada station Kelowna AWOS (1123965) from July 2007 to October 2008, including the corresponding normals (1971-2000). Original data source: Environment Canada, Climate Data Online at: http://climate.weatheroffice.ec.gc.ca/climateData/canada_e.html (accessed 21-Sep-11).

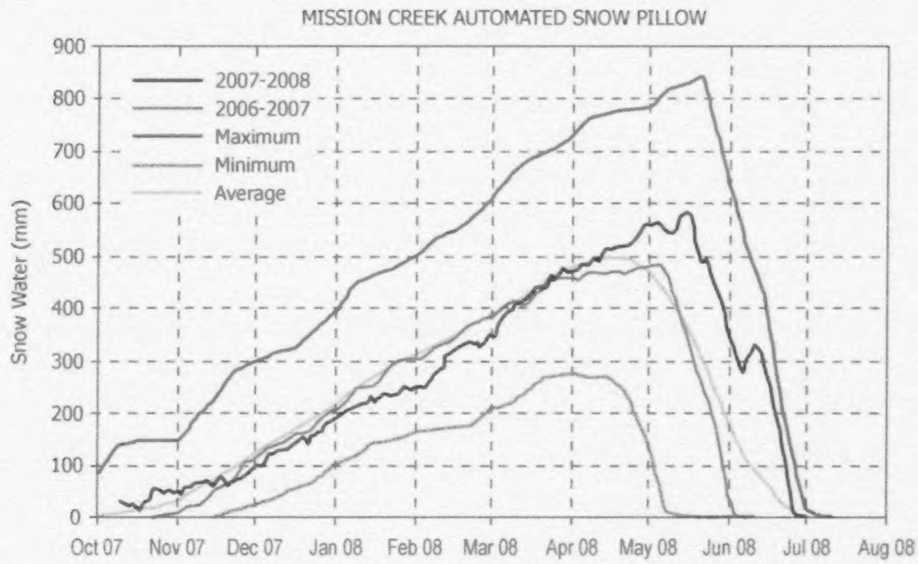
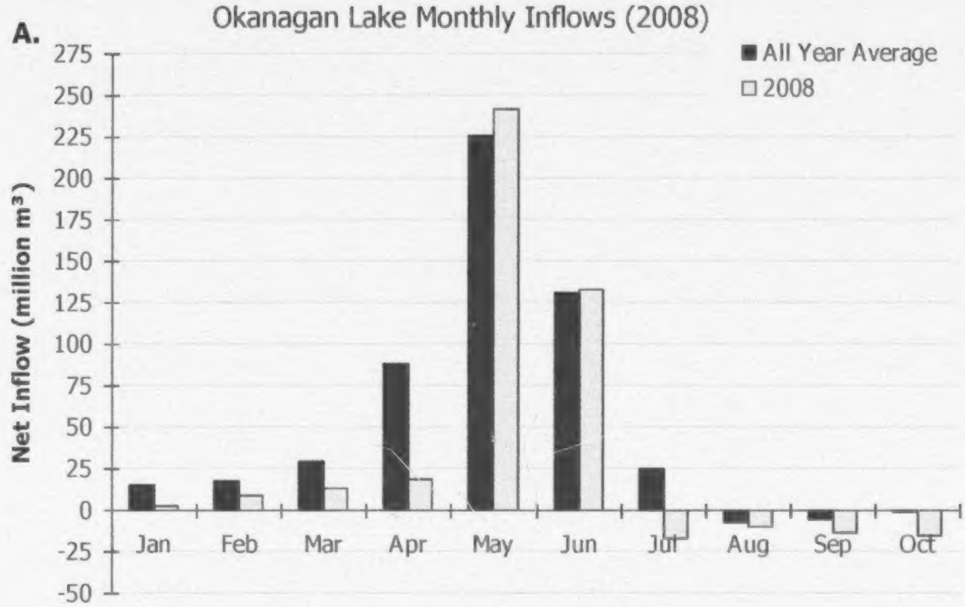


Figure 7. (A) Snow-water equivalents from high elevation (1794m) Mission Creek Snow Pillow station for water year 2008 (grey line) compared to all-year average, maximum and minimum values (38 years of record). (B) Snow-water equivalents from low elevation (1453m) Brenda Mine Snow Pillow station for water year 2007 (grey line) compared to all-year average, maximum and minimum values (16 years of record). Snow-pack from Mission Creek sub-basin contributes approximately one third of the annual net inflow to Okanagan Lake. Source: British Columbia River Forecast Centre accessed (15-Sep-08) from: http://bcrfc.env.gov.bc.ca/data/asp/realtime/basin_okanagan_kettle.htm



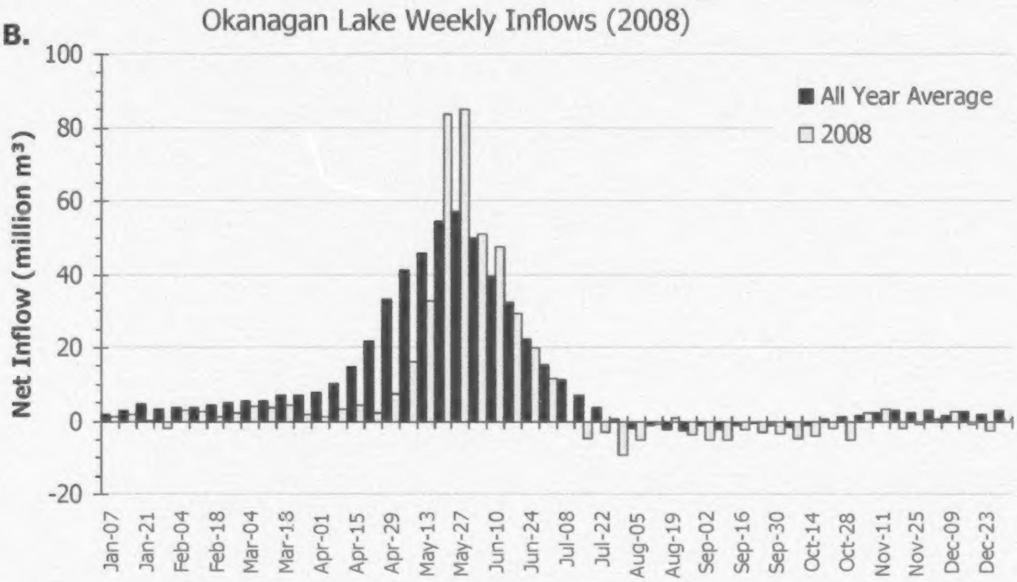


Figure 8. (A) Monthly and (B) weekly net inflows (in million m³) from all tributaries into Okanagan Lake for 2008 (blue bars) and the average across all years (black bars) from 1921-2007. Negative inflows in Aug-Sept result from water withdrawals for irrigation and evaporative losses from Okanagan Lake.

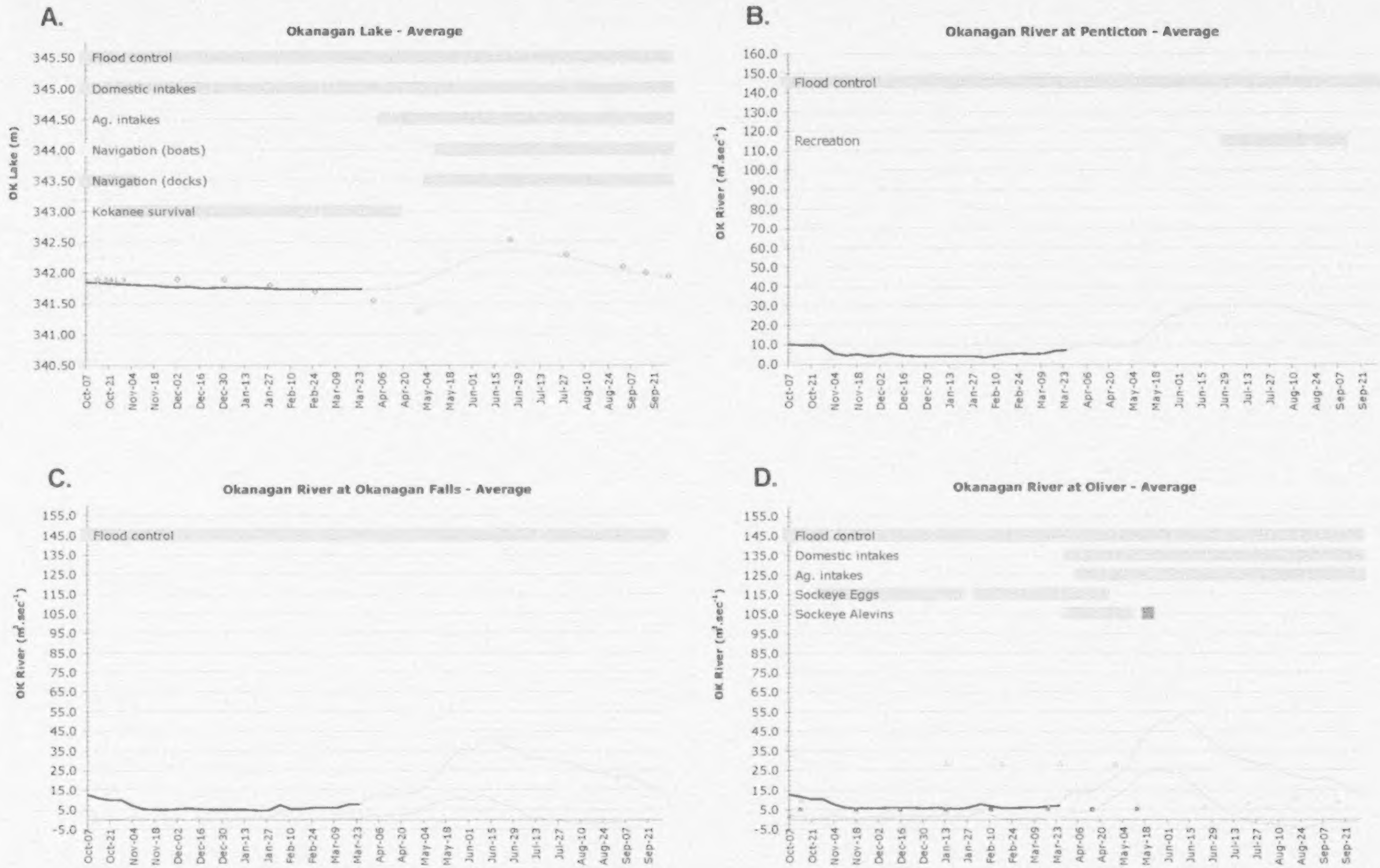


Figure 9. FWMT Scenario 484 run by Kim Hyatt on March 25, 2008 which indicates that spills could immediately be increased to 10-12 cms (currently at 7.2 cms; Panel B) with additional increases of up to 15-25 cms beginning in mid-May (Panel B) and result in no risk to kokanee (Panel A). Chart symbols are explained in Figure 3.

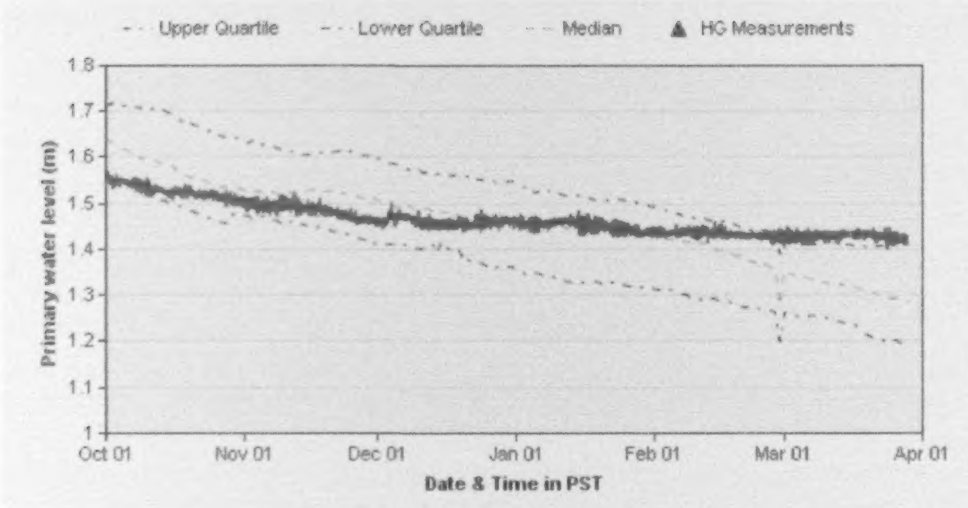


Figure 10. Screen capture of Okanagan Lake level (Okanagan Lake at Kelowna, 08MN083) October 2007 to April 1 2008 illustrating current level (solid blue line) as compared to all year upper, lower, and median levels. Source: Environment Canada, Water Survey of Canada, Real-Time Data, at:
http://www.wateroffice.ec.gc.ca/text_search/search_e.html?search_by=p&region=BC

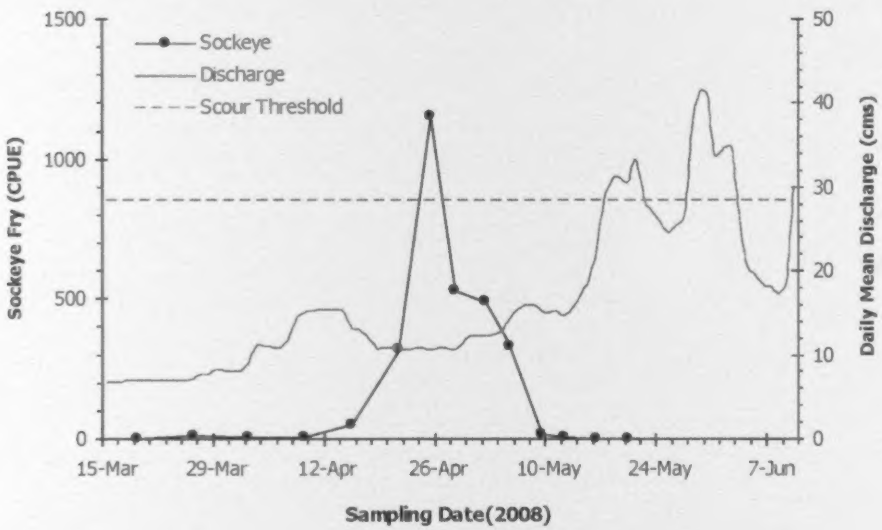


Figure 11. Okanagan River fry emergence timing in the spring of 2008 as determined by fyke net sampling at Vertical Drop Structure 13. Peak emergence was observed on the sampling date of April 22; 98% emergence was observed on the sampling date of May 9.

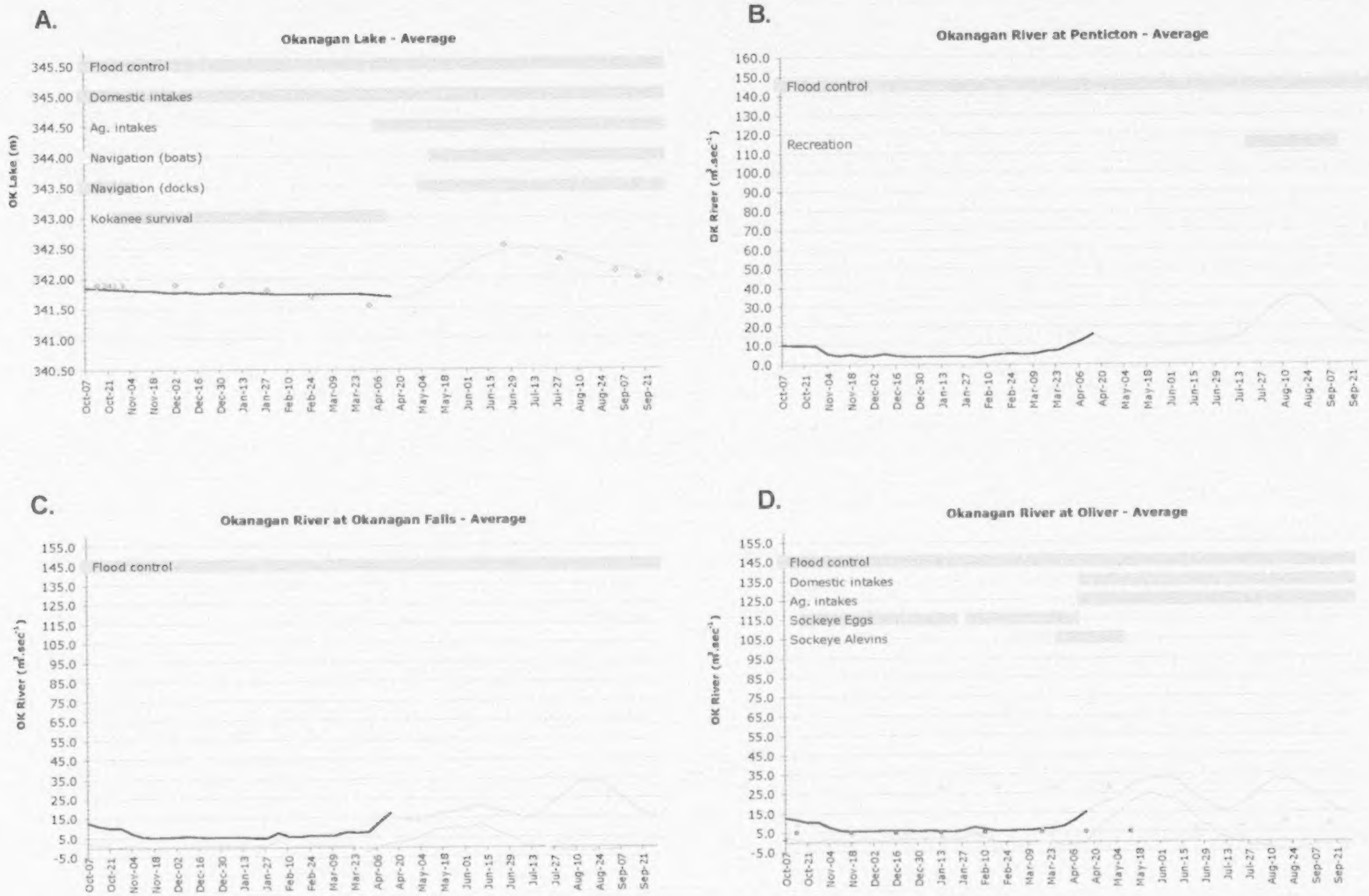


Figure 12. FWMT Scenario 489 run by Kim Hyatt on April 14, 2008. Chart symbols are explained in Figure 3

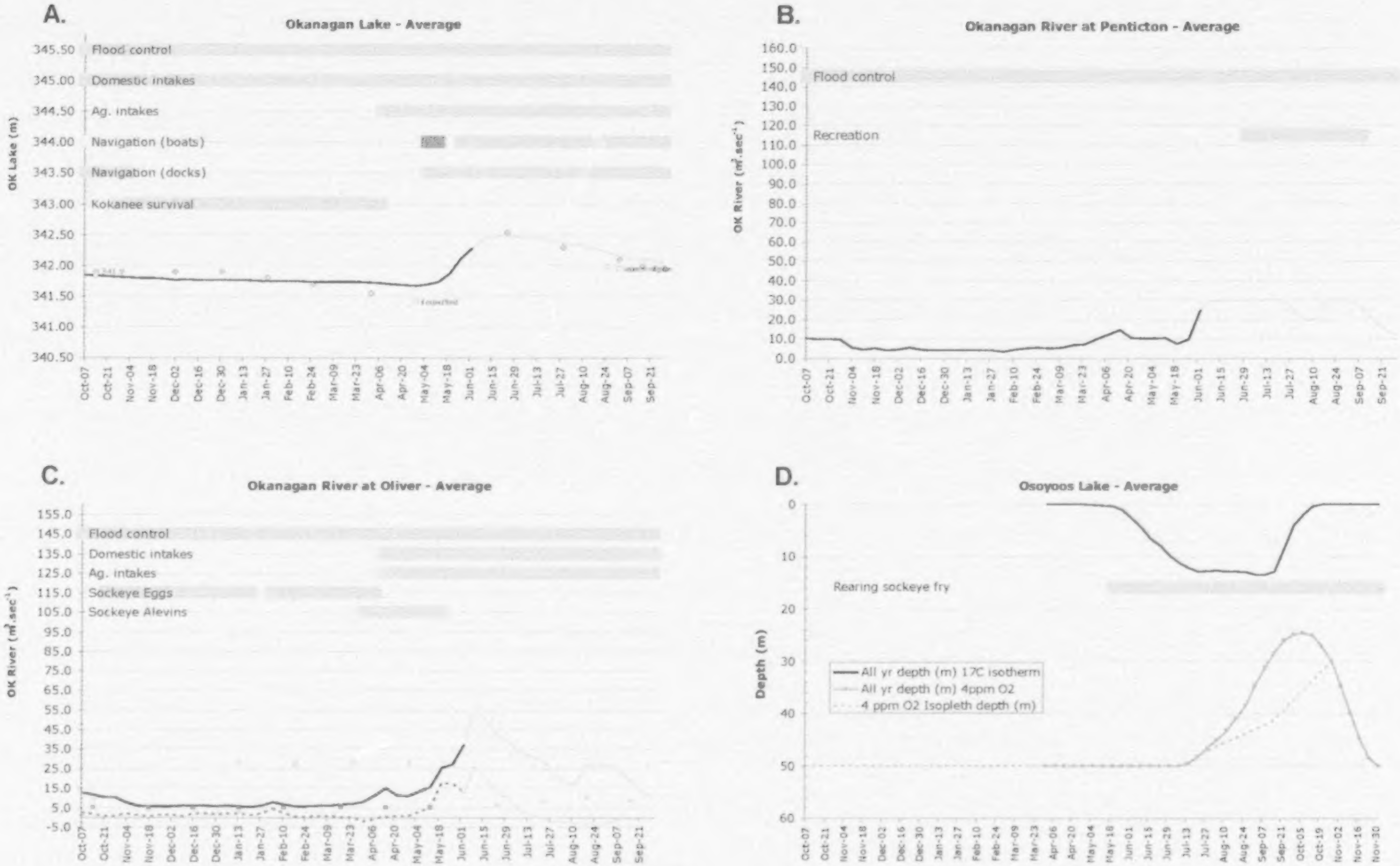


Figure 13. FWMT Scenario 498 run by Margot Stockwell on June 2, 2008. Chart symbols are explained in Figure 3. Note that some graphic displays were amended in May 2008. In chart C, dashed black lines represent observed unregulated tributary contributions; dashed blue lines are predicted unregulated tributary contributions. In chart D, the solid black line represents the all year (1994-2007), daily mean depth of the 17°C isopleth; the pink line represents the all year, daily mean depth of the 4 ppm O_2 isopleth. The red dashed line represents the predicted depth of the in-season 4ppm O_2 isopleth.

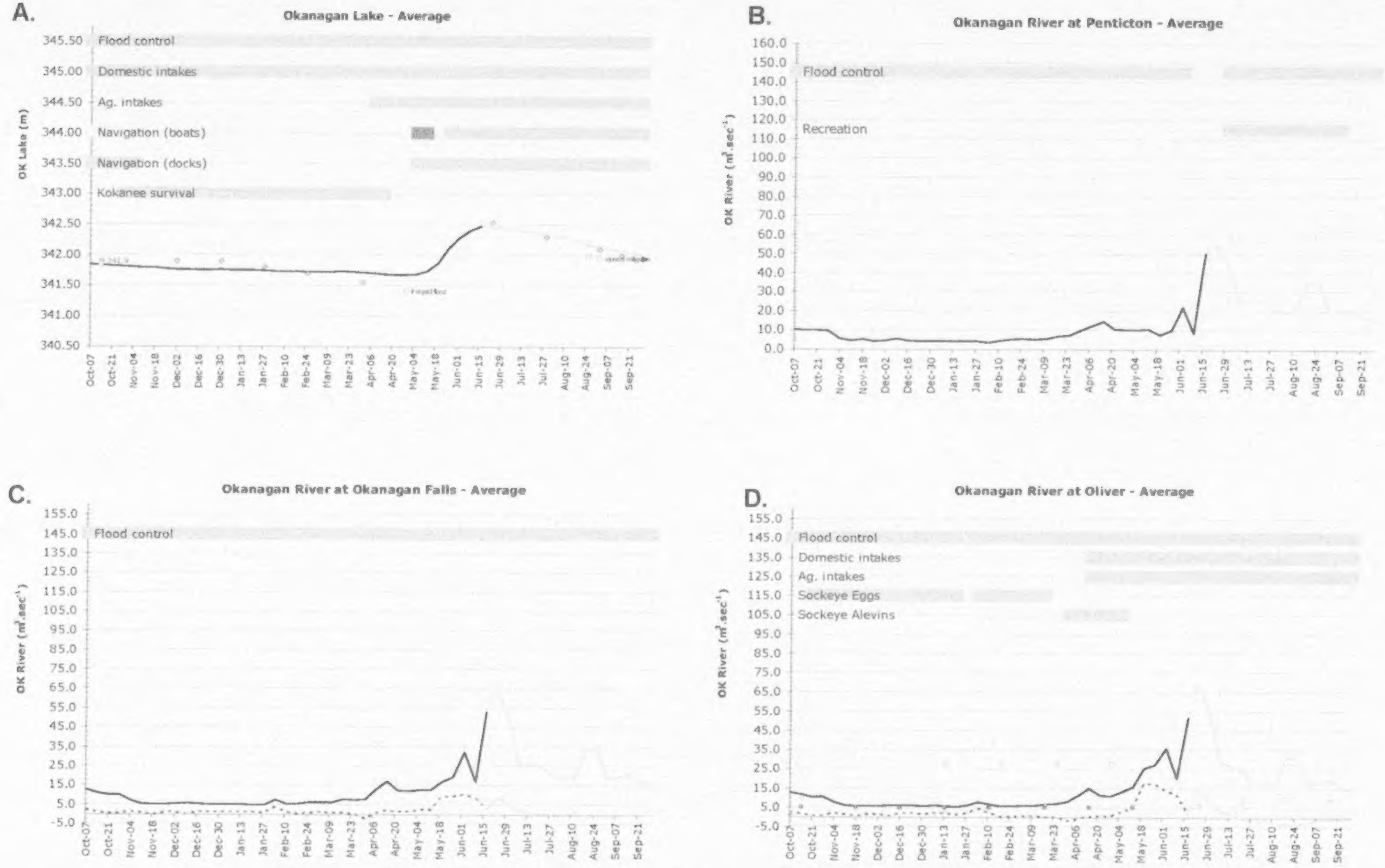
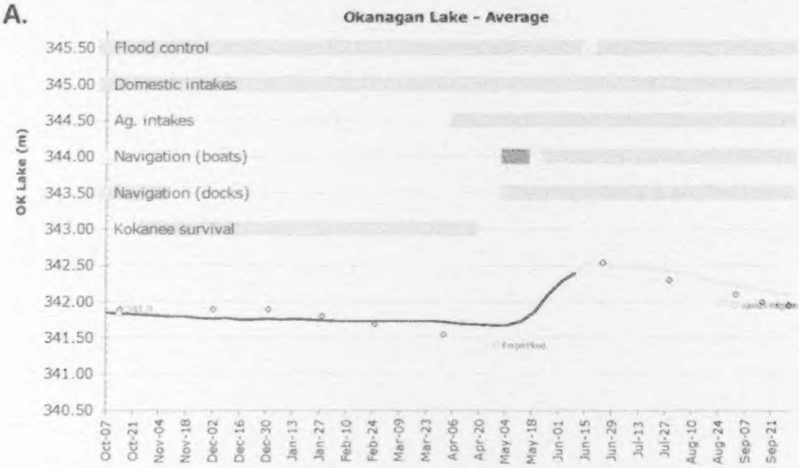


Figure 14. FWMT Scenario 497 run by Des Anderson on June 12, 2008. Okanagan Lake level is on a trajectory to exceed full pool (flood risk). Aggressive water releases (Panel B) are required in order to prevent the lake from surpassing full pool at the June 24th benchmark (green circle, Panel A). Chart symbols are explained in Figure 3 and 14.

A.



B.

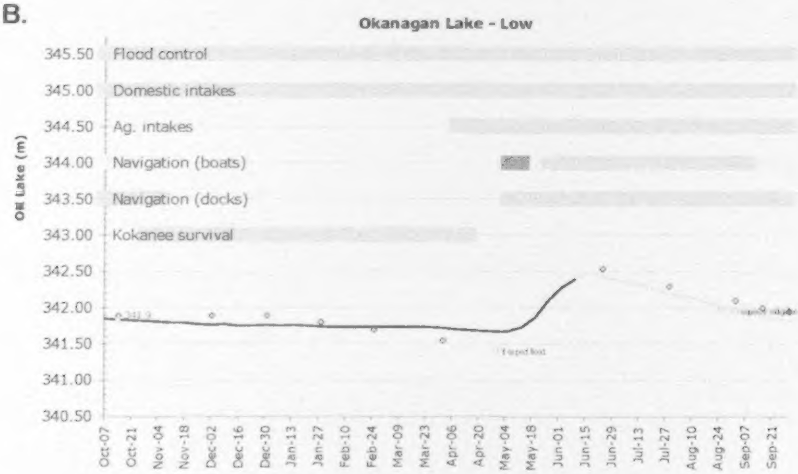


Figure 15. FWMT Scenario 501 run by Clint Alexander on June 10, 2008. Scenarios run at the average RFC May inflow forecast (A) or low forecast (B; Table 5) indicate that Okanagan Lake will likely crest before reaching full pool despite FWMT predictions (blue line). The predicted date of full pool is likely exaggerated in FWMT as shown by the discrepancy in trajectory between real-time data (black line) and predicted lake elevation (blue line). This is an effect of the weekly disaggregation algorithm used by the model for forecasting.

Figure 16. Okanagan sockeye salmon returns and pre-season forecasts as observed at Wells Dam on the Columbia River.

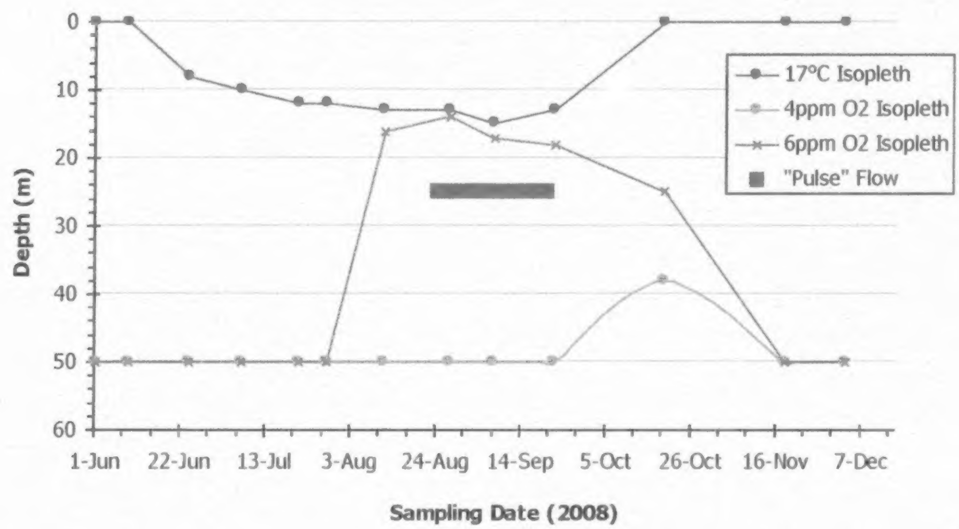


Figure 17. Depths of the 17°C, 6ppm O_2, and 4ppm O_2 isopleths in the North Basin of Osoyoos Lake during 2008. The blue bar indicates the duration of the increased "pulse" flow of 30 cms. Optimal juvenile rearing habitat is the depth interval at which water temperature is <17°C and dissolved oxygen concentration is >4ppm. The severity of a squeeze event is indicated by the level of convergence of the 17°C and 4 mg/litre oxygen isopleths (Hyatt et al. 2009).

A.

B.

C.

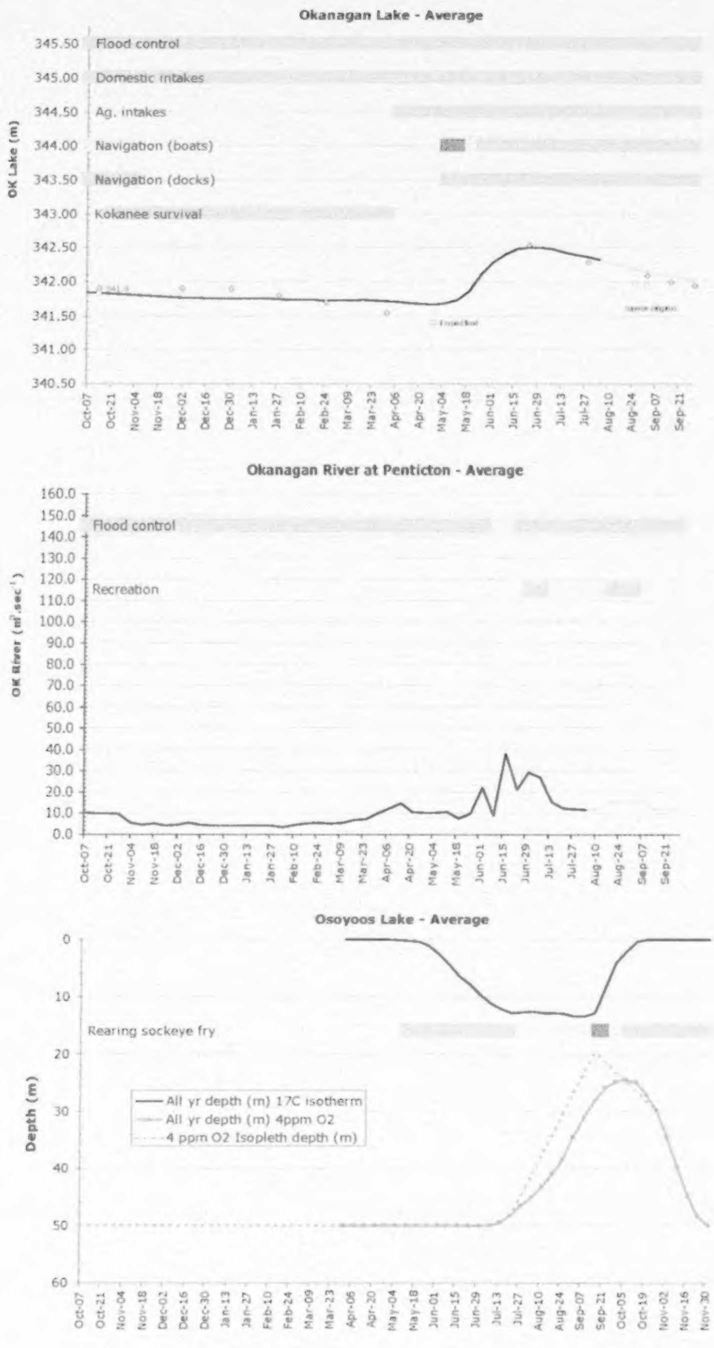


Figure 18. FWMT Scenario run by Margot Stockwell on Aug. 4, 2008. Maintaining discharges of 12-15 cms from Penticton Dam (Panel B) will induce a squeeze event in Osoyoos Lake (Panel C).

A.

B.

C.

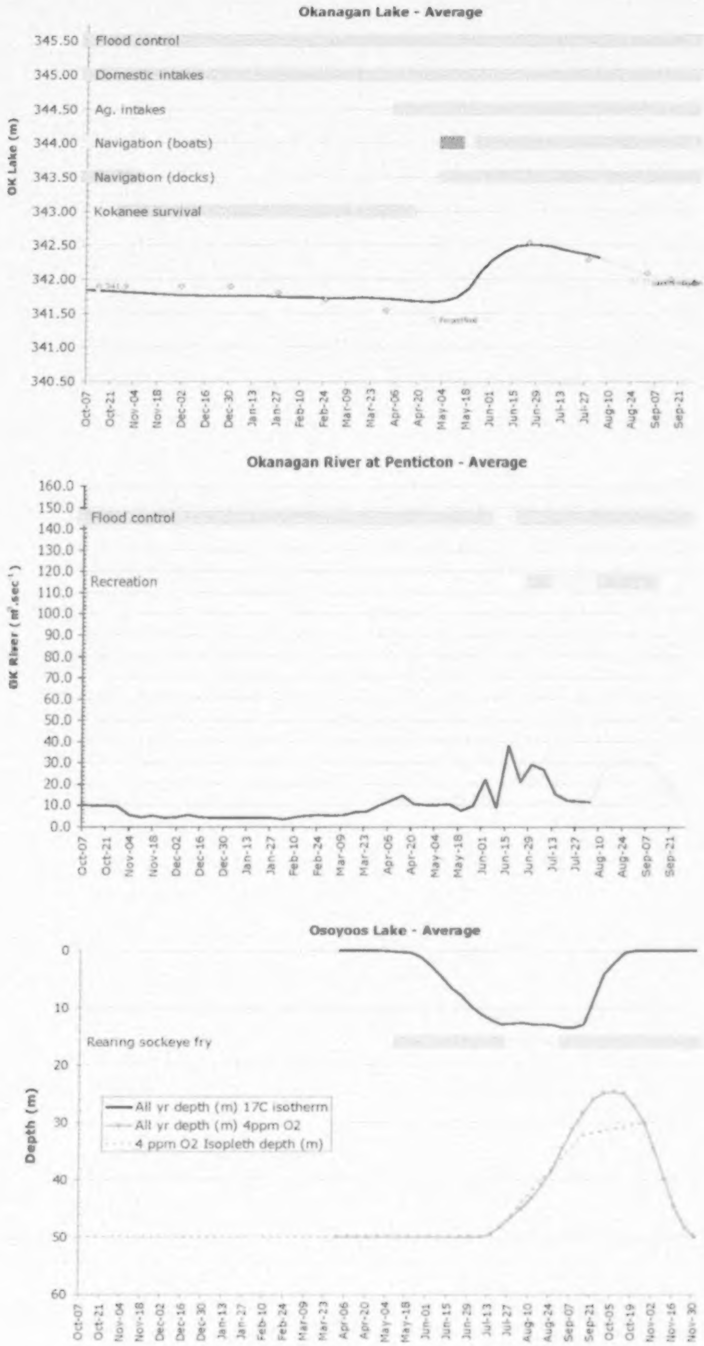


Figure 19. FWMT Scenario run by Kim Hyatt on Aug. 5, 2008. A release of a pulsed flow of water of 30-35 cms (Panel B) for a 3 week interval between August 22nd and Sept 15th will impede development of severe squeeze conditions (Panel C). Releases of this magnitude and duration may be implemented without undue risk of drafting Okanagan Lake below preferred fall benchmarks for beach spawning by kokanee in Okanagan Lake (Panel A).

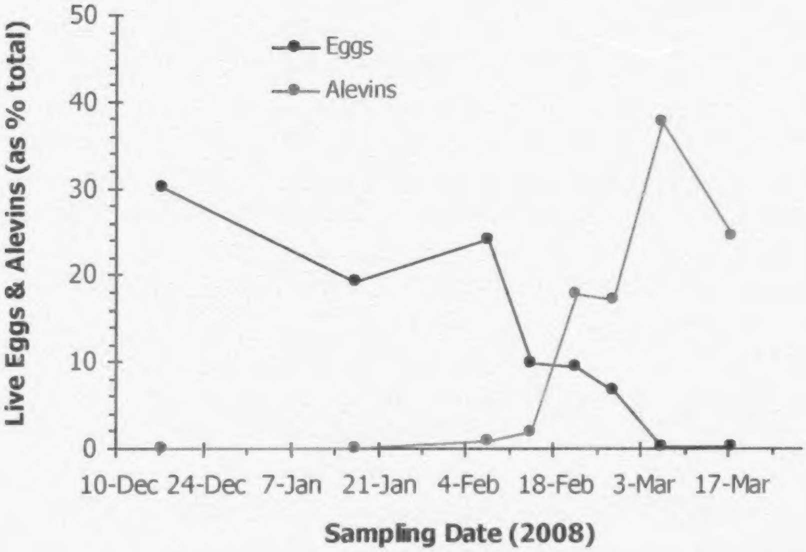


Figure 20. Sockeye egg hatch timing as observed by hydraulic sampling of redds on the Okanagan River sockeye spawning grounds. Abundance of eggs and alevins per date is percent of total live eggs or alevins sampled across the season, pooled for 3 transects. Sampling indicate that hatch was 100% complete by March 6, 2008.

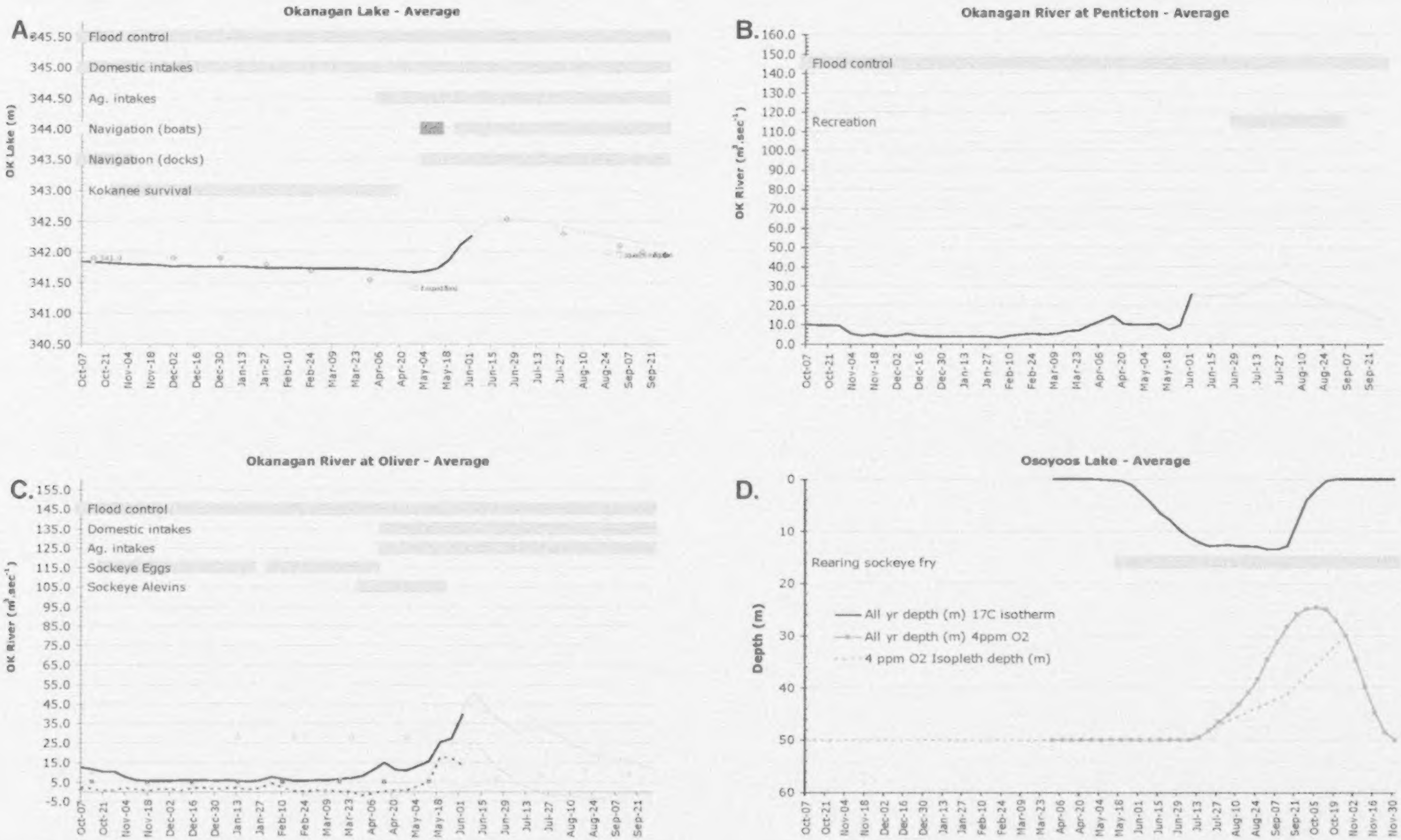
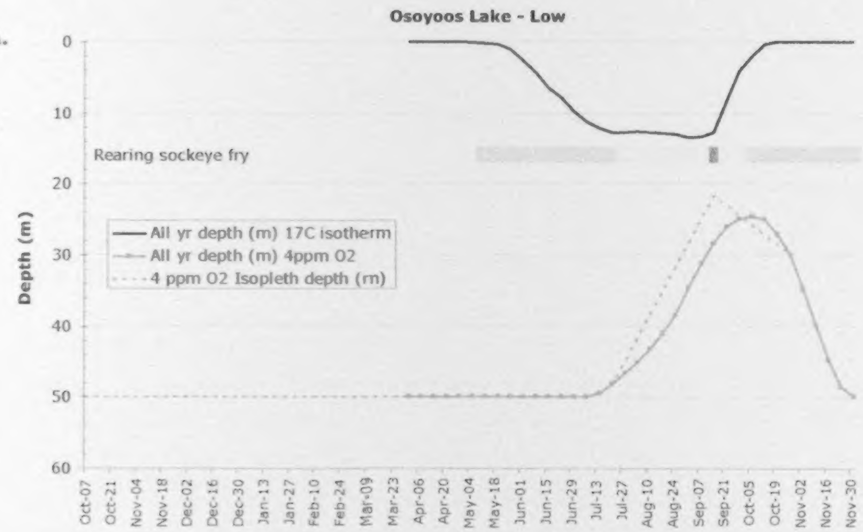


Figure 21. Scenario 495 run by Kim Hyatt on May 30, 2008. Unregulated tributary inflows (Panel C)have peaked and are declining so model projections suggesting unregulated tributaries will spill more water may be ignored. FWMT suggests water supplies are sufficient to meet spill levels required to suppress any severe squeeze effect (Panel D). Chart symbols are explained in Figure 3 and 14.

A.



B.

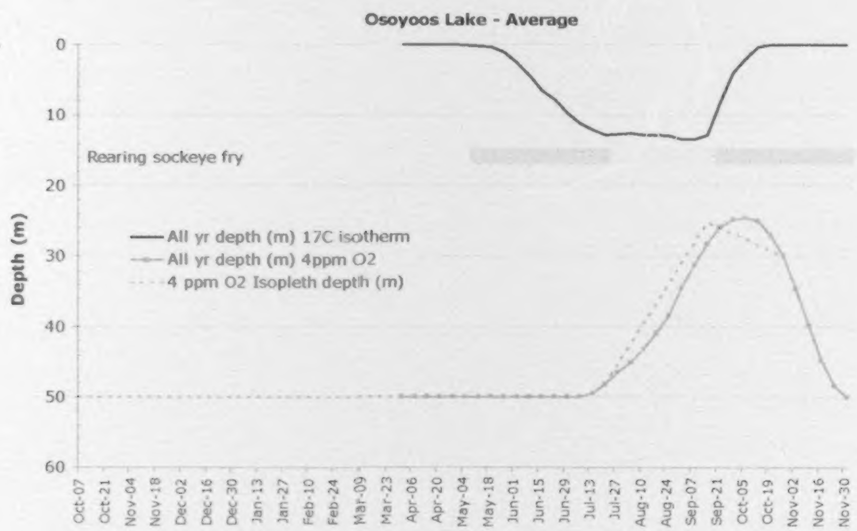


Figure 22. Outlook for potential temperature-oxygen squeeze event as depicted in Scenario 506 run by Kim Hyatt on July 27, 2008. If drier than normal summer conditions persist through Aug-Sept, then the “graphs low” version (Panel A) appears most likely and suggests the possibility that a late summer-fall temperature-oxygen squeeze may be induced in Osoyoos Lake. Graphs-average (Panel B) suggests that average rainfall and associated water releases through August and Sept. will avoid development of a severe habitat-limiting “squeeze” condition for juvenile sockeye rearing in Osoyoos Lake.

Appendix 1. Submission form to nominate the Fish-Water-Management-Tool Program for the 2007/2008 British Columbia Premier's Award for Innovation and Excellence

PREMIER'S AWARDS

Submission Form

PARTNERSHIP

Name of Eligible Organization Supporting this Nomination

(Eligible Organizations)

Ministry of Environment

Region (If multi-regional, place an 'X' in all that apply)

X Interior   Lower Mainland/Fraser Valley   North   Vancouver Island

Name of Nominated Branch, Program, Group, Team, or Individual Employee
Okanagan Basin Fish-Water Management Team

Contact Name
Al Martin

Title
Executive Director Fish Wildlife and Ecosystems

Email
Al.Martin@gov.bc.ca

Phone Number
250-387-9788

Mailing Address
PO Box 9394 Stn Prov Govt, Victoria, BC, V8W 9M8

Submission Approved by the Deputy Minister or Equivalent? YES__ NO__

Nominee Information

	Name	Branch or Program Area	Phone	Email	Mailing Address
1	Steve Matthews	MOE Fish and Wildlife	250-490-8243	Steve.Matthews@gov.bc.ca	102 Industrial Place, Penticton, BC, V2A 7C8
2	Brian Symonds	MOE Water Stewardship	250-490-8255	Brian.Symonds@gov.bc.ca	102 Industrial Place, Penticton, BC, V2A 7C8
3	Deana Machin	Okanagan Nation Alliance	250-707-0095	Deanamachin@syilx.org	3255 C Shannon Lake Road, Westbank, BC, V4T 1V4
4	Howie Wright	Okanagan Nation Alliance	250-707-0095	HWright@Syilx.Org	3255 C Shannon Lake Road, Westbank, BC, V4T 1V4
5	Kim Hyatt	Fisheries and Oceans Canada	250-756-7217	HyattK@pac.dfo-mpo.gc.ca	3190 Hammond Bay Road, Nanaimo, BC, V9T 6N7

6	Margot Stockwell	Fisheries and Oceans Canada	250-756-7120	StockwellM@pac.dfo-mpo.gc.ca	3190 Hammond Bay Road, Nanaimo, BC, V9T 6N7
7	Rick Klinge	Douglas County Public Utility District	509-884-7191	Rklinge@dcpud.org	1151 Valley Mall Parkway, East Wenatchee, WA 98802, USA
8	Clint Alexander	ESSA Technologies	250-860-3824	Calexander@essa.com	1479 Aspen Court, Kelowna, BC, V1Y 3R3

For group or team nominations, please restrict size to 10 or fewer members, if possible. Indicate below if the group or team has more than 10 members. In such cases, the contact person will be consulted by the Premier's Awards Program.

If this is a group or team nomination, does the group or team have more than 10 members?
YES__ NO_X_

Summary Statement

Synopsis of submission. Not to exceed 50 words. To be published on The Premier's Awards website and in the awards ceremony program guide along with the names of the nominee(s) and their ministry or organization.

The Okanagan Fish-Water Management Team exemplifies partners working together to achieve multi-stakeholder water and fisheries management goals in the face of climate change. The team comprises provincial and federal governments, First Nations, and the private sector. Together, they developed an innovative computer model which has achieved significant benefits since 2005/06.

PARTNERSHIP **Detailed Submission** (1,500 word limit)

The submission should describe a creative and effective joint or multi-party initiative with other provincial entities, other levels of government, the private and non-profit sectors, First Nations, etc. At least one of the partners must be outside the BC Public Service.

Please provide the reasons for this nomination by describing the context (optional) and addressing each of the criteria elements. Only the parts of the submission that address the criteria will be rated.

Context (optional)

The Okanagan River system has been substantially modified by human activities over the past century including considerable urban and agricultural development. The river was channelized and regulated by a dam at the outlet of Okanagan Lake to protect surrounding communities following wide-spread flooding in the 1940s. The entire system, including Okanagan Lake, the river, and all downstream lakes, is affected by water regulation. Kokanee and sockeye salmon depend heavily on habitat in the Okanagan system. Spawning habitat, in particular, is affected by changes in water levels as eggs can be exposed to the air at low water levels or scoured out of the gravel at high water levels. In the past up to 30% of a year class for kokanee or sockeye could be lost due to water level fluctuation.

Water managers in the Okanagan system are faced with complex decisions to balance fisheries values, flood control, and other water allocation objectives. Specifically, they must manage water release at the Okanagan Lake dam to meet multiple socio-economic objectives (prevent flooding, maintain adequate water for domestic and agricultural intakes, preserve recreational access) and ecological objectives (sufficient water for kokanee that spawn along the margins of Okanagan Lake and sockeye that spawn within the Okanagan River). These decisions are complicated by the timeframe they are made in and the uncertainty around possible flood levels and fish development. To accommodate spring high water without flooding communities either adjacent to the lake or the river downstream, water managers must start drawing down Okanagan Lake in early winter. However, as the lake is lowered, kokanee eggs are damaged or killed when spawning areas are exposed to air. Not drawing down the lake through the winter results in Okanagan River flows having to be increased in the spring which can wash out sockeye

eggs and juveniles incubating in the river gravel. The challenge for water managers is being able to prevent flooding while predicting how much snow will accumulate through the winter, how far to draw the lake down without damaging kokanee, and when to release water downstream in a fashion that will not impact sockeye.

To support scientifically defensible decisions by water managers, the Okanagan Fish-Water Management Team (a partnership of provincial and federal governments, First Nations, and the private sector) came together in 2001 to develop an innovative science-based computer model. Funding for the initiative (in excess of $1,000,000 since 2001) was provided by the Douglas County Public Utility District in Washington State which was interested in mitigating sockeye losses incurred at their dam facilities on the Columbia River. The result of this partnership is a software program that automates complex biophysical calculations using real-time data on water inflow to Okanagan Lake and incorporating kokanee and sockeye information to show how well objectives have been met. Since it became operational in 2005/06, the model has increased collaborative decision-making and has resulted in significant fisheries and flood protection benefits. An analysis completed by the team indicated that juvenile sockeye production could be increased by as much as 55% through use of the tool.

Breadth and degree of impact on the community

(e.g. social, economic & environmental benefits)

The Fish-Water Management Team developed a computer model to support water managers in making decisions and trade-offs that maximize socio-economic goals and environmental benefits in the Okanagan Valley as they pertain to flood management. The primary goal of water managers in the Okanagan is to manage lake levels and river discharge to avoid flooding in communities adjacent to these water bodies. While this may be achieved, the issue of also protecting the fish resources in the lake (no de-watering of kokanee eggs) and river (no de-watering or flushing out of sockeye eggs) adds considerable complication. Okanagan River sockeye salmon have been declining in abundance since the 1950s and are frequently insufficient in number to support even modest harvest levels by First Nations. Similarly, the kokanee population of Okanagan Lake has been in rapid decline with the recreational fishery closed in the mid-1990s to conserve dwindling stocks.

The water management tool has been used on an operational basis in 2005-06 and 2006-07. In both years the model proved to be highly successful at bringing the project partners together and ensuring that consensus was reached in how water levels would be managed to achieve the group's diverse objectives. The results have been that in both years no flooding has occurred around Okanagan Lake or River downstream, and both kokanee and sockeye management objectives have been achieved. Following the 2006 water year, Brian Symonds, the Director of Regional Operations with the Water Stewardship Division remarked on the effectiveness of the computer model, noting that "Overall I feel that the tool enabled the [Okanagan] system to be managed in a transparent and cooperative manner, while at the same time balancing and meeting the objectives of all parties involved in fisheries management despite the challenges presented".

A 25-year retrospective analysis completed by the Okanagan Fish-Water Management Team identified that sockeye smolt production could increase by 55% without adversely impacting flooding or other economic interests. Similar benefits to kokanee production are also expected from on-going use of the model. Social and economic benefits accruing from use of the tool include less possibility of flooding around the lake and river downstream and the maintenance of agriculture and domestic water intakes.

Breadth and degree of impact on operations

The model developed by the Okanagan Fish-Water Management Team provides a number of benefits for the Ministry of Environment and the Province of British Columbia. The model identifies water management strategies to reduce the possibility of flooding communities around Okanagan Lake or the Okanagan River downstream. This in turn results in less litigation or settlements resulting from flooded properties along these systems.

A further positive impact on operations is the optimization of water releases to minimize impacts and repairs on flood control works on the Okanagan system. By managing around the possibility of extreme flows, less or no damage is done to dykes, flow control structures and dams.

The kokanee population of Okanagan Lake benefits from the team's development of the computer model. By minimizing damage to eggs or incubating juveniles, survival of kokanee is increased. With more kokanee in the lake, the Okanagan Lake recreational fishery will be maintained and will provide both social and economic benefits and will result in a rebuilding of angler numbers in the area.

The tool has further impacts on operations by building support for water management decisions but also building better relationships with team partners. Jim Mattison, Assistant Deputy Minister of the Water Stewardship Division noted that "The tool has really helped, not only improving our operation of the [Okanagan] River, but also greatly improving stakeholder and public understanding of the decisions that we make".

Alignment with public service vision and values, and government direction

One of the government's Five Great Goals is to "Lead the world in sustainable environmental management, with the best air and water quality, and the best fisheries management, bar none". Through dedicated teamwork, innovation, and leadership, members from the Ministry of Environment, Fisheries and Oceans Canada, the Okanagan Nation Alliance, the Douglas County Public Utility District and ESSA Technologies successfully developed a model to achieve sustainable environmental management, and contribute to the best fisheries management bar none.

The team's work and the model they developed furthermore align with government direction by clearly providing adaptation strategies to offset some of the impacts of climate change. Water demand in the Okanagan is increasing in the face of population growth and changing land use combined with the impacts of climate change. By using the predictive capabilities of the tool, water management strategies can be developed to not only address flood and fish objectives in the spring, but also storage and release strategies through the summer and fall to ensure sufficient water is available to support fish populations through this critical period.

Complexity

(e.g. scope of initiative, risk, creativity, technical and/or organizational difficulty (including financial constraints)

The Okanagan Fish-Water Management Team has developed a cutting-edge and innovative computer model that allows all of the team members to participate and agree on trade-offs to best meet the collective socio-economic and environmental goals associated with water management in the valley. The challenge facing the team was to develop a predictive computer tool to balance the demands between flooding, fisheries, agriculture and urban water supply and other interests in the face of climate change. This was further complicated by the value differences and contrasting objectives that each of the partners brought to the table. However, the team has developed a better appreciation for each of the parties' value differences, thereby facilitating the achievement of consensus in water management decisions.

The Team used their combined expertise and the resources of the Douglas County Public Utility District (in excess of $1,000,000) to develop a science-based decision support system that uses the internet to bring together water and fisheries managers located around the province to make the best decisions possible to address the needs of people and fish. The team work, innovation, and dedication shown by the Okanagan Fish Water Management Team is a shining example of what can be achieved when we work together to achieve multiple objectives.